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RE SITING INVESTIGATION. GRAVITY SURVEY - COAL VALLEY, NEVADA. (U)

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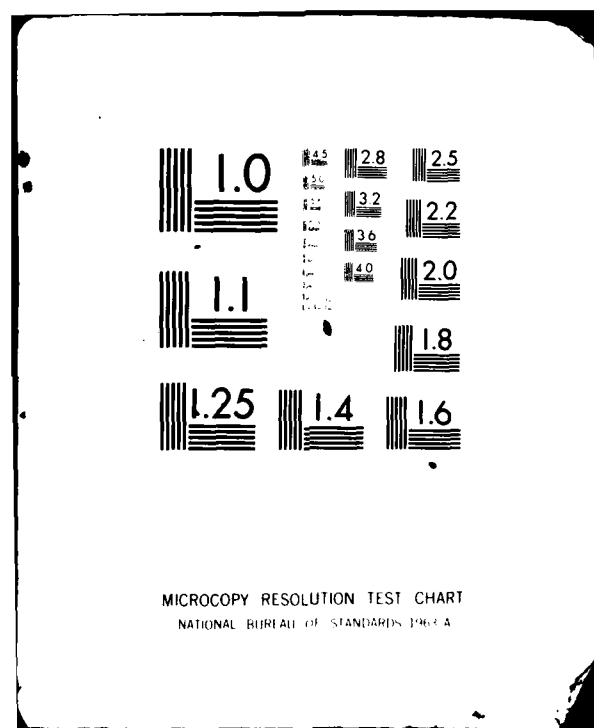
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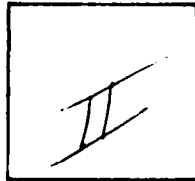
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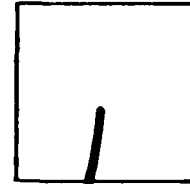
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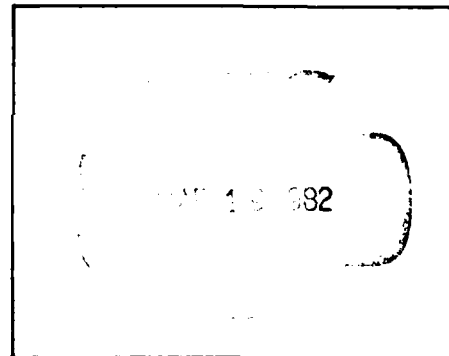
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MX SITING INVESTIGATION
GRAVITY SURVEY - COAL VALLEY
NEVADA

Prepared for:

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30 May 1980

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
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FOREWORD

Methodology and Characterization studies during fiscal years 1977 and 1978 included gravity surveys in ten valleys in Arizona (five), Nevada (two), New Mexico (two), and California (one). The gravity data were obtained for the purpose of estimating the gross structure and shape of the basins and the thickness of the valley fill. There was also the possibility of detecting shallow rock in areas between boring locations. Generalized interpretations from these surveys were included in Fugro National's Characterization Reports (FN-TR-26a through e).

During the FY 77 surveys, measurements were made to form an approximate one-mile grid over the study areas and contour maps showing interpreted depth to bedrock were made. In FY 79, the decision was made to concentrate on verifying and refining suitable area boundaries. This decision resulted in a reduction in the gravity program. Instead of obtaining gravity data on a grid, the reduced program consisted of obtaining gravity measurements along profiles across the valleys where Verification Studies were also performed.

The Defense Mapping Agency (DMA), St. Louis was requested to provide gravity data from their library to supplement the gravity profiles. For Big Smoky, Reveille and Railroad valleys, a sufficient density of library data is available to permit construction of interpreted contour maps instead of just two-dimensional cross sections.

In late summer of FY 79, supplementary funds became available to begin data reduction. At that time inner zone terrain corrections were begun on the library data and the profiles from Big Smoky Valley, Nevada, and Butler and La Posa valleys, Arizona. The profile data from Whirlwind, Hamlin, Snake East, White River, Garden and Coal valleys, Nevada became available from the field in early October, 1979.

A continuation of gravity interpretations has been incorporated into the FY 80 program and the results are being summarized in a series of valley reports. In reports covering Nevada-Utah gravity studies will be numbered, "FN-TR-33-", followed by the abbreviation for the subject valley. In addition, more detailed reports of the results of FY 77 surveys in Dry Lake and Ralston valleys, Nevada are being prepared. Verification studies are continuing in FY 80 and gravity studies are included in the program. DMA will continue to obtain the field measurements and it is planned to return to the grid pattern. The interpretation of the grid data will allow the production of contour maps which will be valuable in the deep basin structural analysis needed for computer modeling in the water resources program. The

gravity interpretations will also be useful in Nuclear Hardness and Survivability (NH&S) evaluations.

The basic decisions governing the gravity program are made by BMO following consultation with TRW Inc., Fugro National and the DMA. Conduct of the gravity studies is a joint effort between DMA and Fugro National. The field work, including planning, logistics, surveying, and meter operation is done by the Defense Mapping Agency Hydrographic/Topographic Center (DMAHTC), headquartered in Cheyenne, Wyoming. DMAHTC reduces the data to Simple Bouguer Anomaly (see Section A1.4, Appendix A1.0). The Defense Mapping Agency Aerospace Center (DMAAC), St. Louis, calculates outer zone terrain corrections.

Fugro National provides DMA with schedules showing the valleys with the highest priorities. Fugro National also recommended locations for the profiles in the FY 79 studies within the constraints that they should follow existing roads or trails. Any required inner zone terrain corrections are calculated by Fugro National prior to making geologic interpretations.

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1	Gravity Station Location Map Coal Valley, Nevada	In Pocket

1.0 INTRODUCTION

1.1 OBJECTIVE

Gravity measurements were made in Coal Valley for the purpose of estimating the overall shape of the structural basin, the thickness of alluvial fill, and the location of concealed faults. The estimates will be useful in modeling the dynamic response of ground motion in the basin and in evaluating groundwater resources.

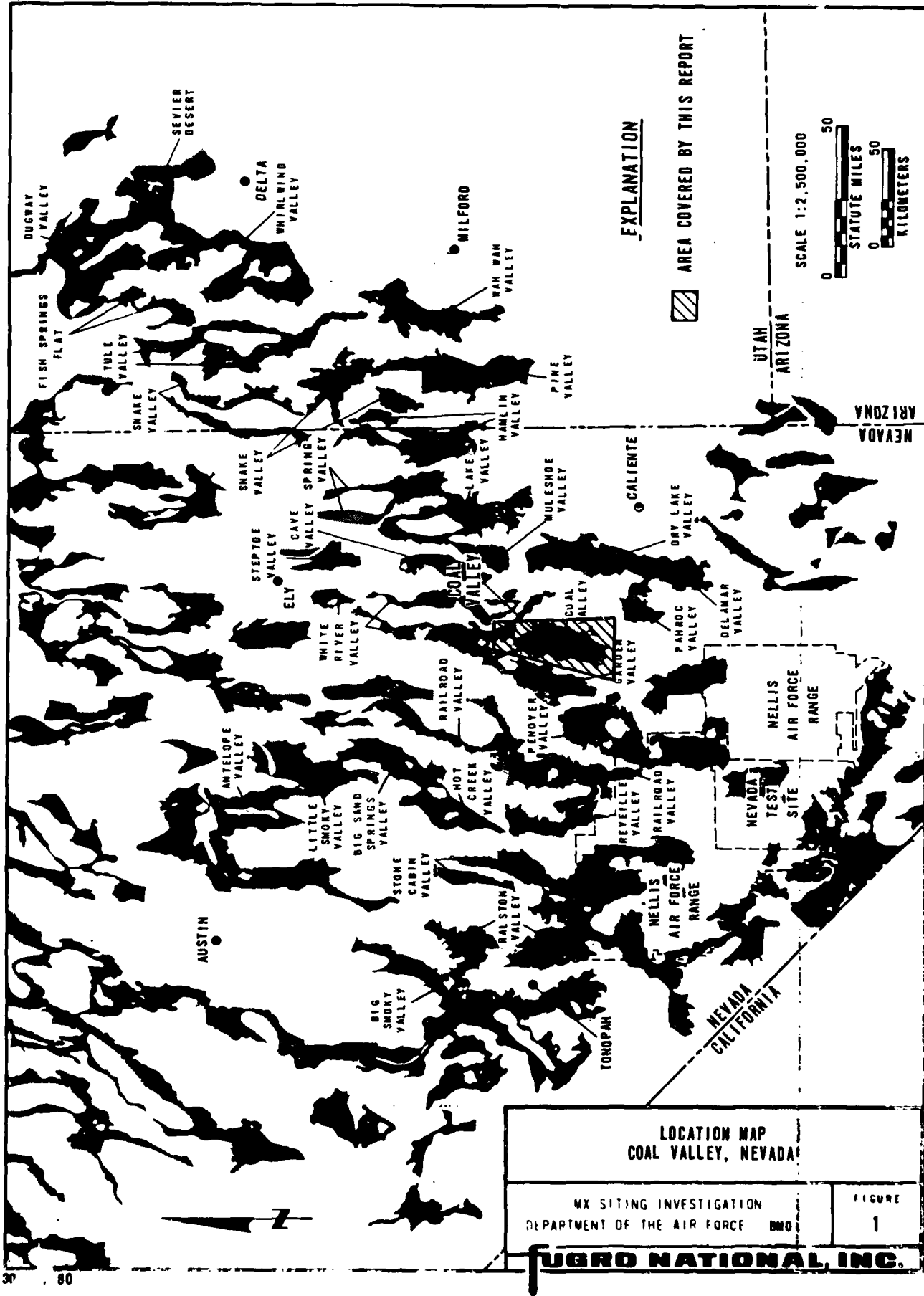
1.2 LOCATION

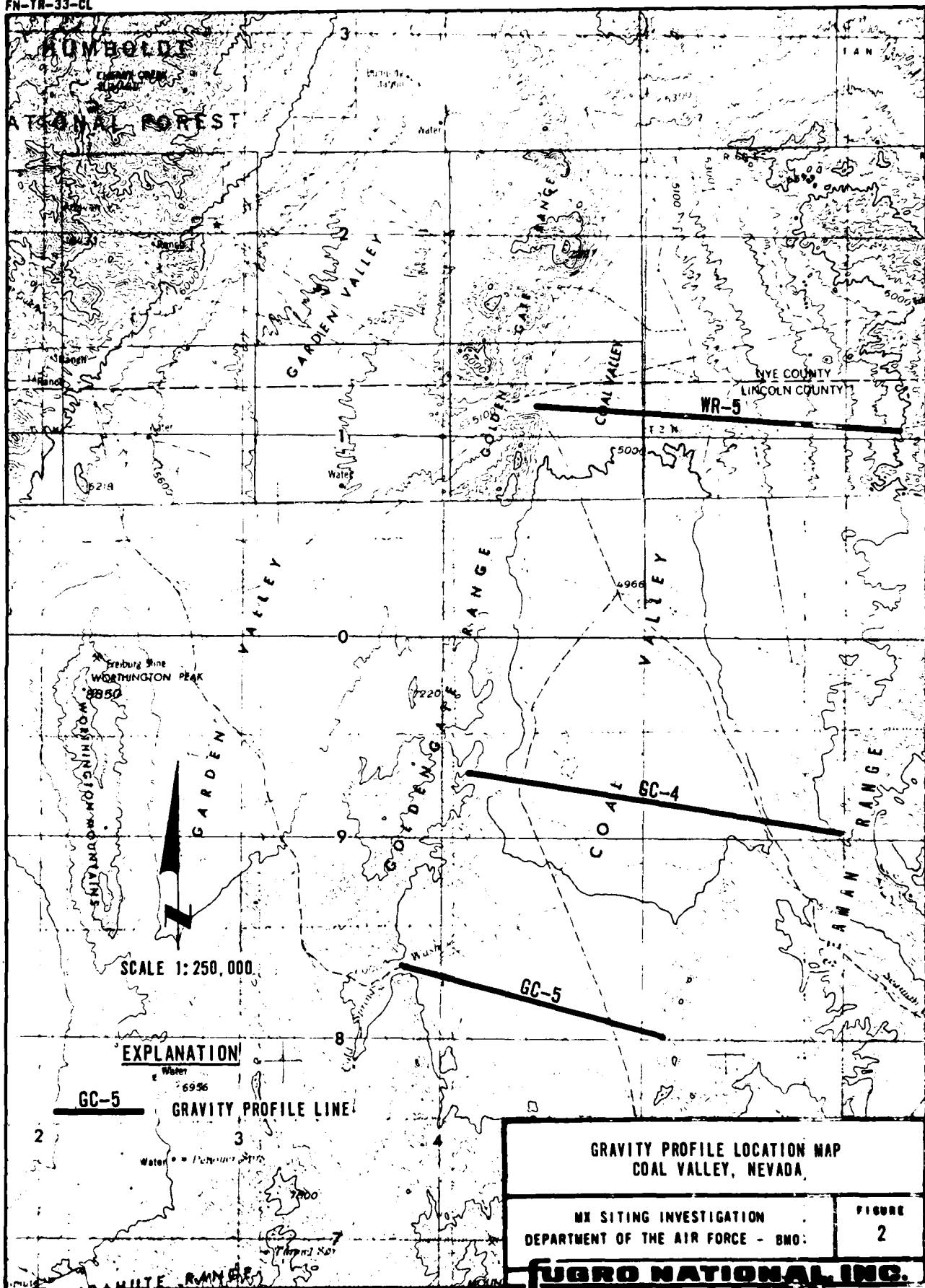
Coal Valley is located in central Nevada (Figure 1) and includes parts of Nye and Lincoln counties. The valley is accessible only by improved and unimproved dirt roads. Caliente, Nevada is located approximately 55 miles (89 km) east of the valley on U.S. Highway 93.

Coal Valley is bounded on the west by the Golden Gate Range, on the south by the North Pahrangat Range and on the east by the Seaman Range (Figure 2). The Seaman Range and Golden Gate Range merge together forming the northern boundary.

1.3 SCOPE OF STUDY

The Defense Mapping Agency Hydrographic-Topographic Center/Geodetic Survey Squadron (DMAHTC/GSS) made the 74 gravity measurements for the three profiles used in this study (Appendix A2.0). Data from the DMA gravity library was also used to establish the regional gravity.





Profile positions are shown in Figure 2 and the locations of the individual stations are shown on Drawing 1. The profile lengths range between 7 miles (11 km) and 11 miles (18 km), crossing over the valley fill from rock outcrop to rock outcrop. The gravity sampling interval is approximately 1-mile (1.6 km) in the central valley and .25 mile (0.4 km) near the valley boundaries. The denser sampling was used near the valley flanks to define any steep gravity gradients associated with boundary faults, and to resolve anomalies with high spatial frequency that could be associated with shallow bedrock.

The tolerance for establishing station elevations was 5 feet (1.5 m). This tolerance for elevation control limits the gravity precision to 0.3 milligals.

2.0 GRAVITY DATA REDUCTION

DMAHTC/GSS obtained the basic observations and reduced them to Simple Bouguer Anomalies (SBA) for each station as described in Appendix A1.0. Up to three levels of terrain corrections were applied to convert the SBA to the Complete Bouguer Anomaly (CBA). First, the Defense Mapping Agency Aerospace Center (DMAAC), St. Louis, used its library of digitized terrain data and a computer program to calculate corrections out to 104 miles (167 km) from each station. When the program could not calculate the terrain effects near a station, a ring template was used to estimate the effect of terrain within approximately 3000 feet (914 m) of the station. The third level of terrain corrections was applied to those stations where 10 feet (3 m) or more of relief was observed within 130 feet (40 m). In these cases, the elevation differences were measured in the field at a distance of 130 feet (40 m) along six directions from the stations. These data were used to calculate the effect of the very near relief. The CBA data for the Coal Valley stations are listed in Appendix A2.0.

3.0 GEOLOGY SUMMARY

Coal Valley is a typical north-south trending valley of the Basin and Range physiographic province. The Golden Gate Range separates Garden and Coal Valleys and consists of westward dipping Paleozoic limestone and dolomite overlain in the north by Tertiary ash-flow tuffs and Quaternary basalt (Howard, 1978). This block is broken by northeast trending faults. The Seaman Range, on the east side of the valley, consists of Devonian and Mississippian limestone, dolomite, and quartzite. These are overlain by a comparatively thin ash-flow tuff layer followed by a complex series of mud flows, lava flows, volcanic breccias, and tuff flows connected with an extinct volcano whose eroded remnants lie east of the center of Coal Valley (Tschanz and Pampeyan, 1970). The northern end of the Seaman Range is broken by numerous north-south and east-west trending faults, most of which appear to predate the valley sediments (Howard, 1978, Fugro National, 1979).

The MX fault study revealed that previously mapped faults (for example Howard, 1978) were lineaments due to vegetation, aeolian, and late Pleistocene-Holocene shoreline features. Gravity data tends to support such an interpretation.

The valley fill consists of 1) alluvial clay, silt, sand, and gravel units and 2) Pleistocene lake deposits ranging also from clayey to gravelly sediments but with clay predominant. The lake deposits comprise about 40 percent of the surficial geology. The alluvial fan deposits make up the remaining

60 percent of surficial deposits and generally occur above the 5100 foot level of the old shoreline (Tschanz and Pampeyan, 1970 and Fugro National FY 78 and 79 data). The lake sediments are probably only a few tens of feet thick, but the valley fill may be several hundred feet thick (although there is little well data to substantiate this) (Eakin, 1963).

4.0 INTERPRETATION

A valley filled with alluvium which has a low-density relative to the surrounding bedrock creates a negative gravity anomaly. Gravity profiles across such valleys are often U-shaped, low in the middle of the valley where the fill is thickest and high on the ends where the fill thins and bedrock emerges. Interpretation requires removal of regional trends leaving the gravity reflection of the valley fill. The gravity data and interpreted geologic models for the three profiles across Coal Valley are shown in Figures 3 through 5.

4.1 REGIONAL-RESIDUAL SEPARATION

A fundamental step in gravity interpretation is isolation of the part of the CBA which represents the geologic feature of interest, in this case the relatively low density valley fill. The portion of the CBA which corresponds to this alluvial material is called the "residual anomaly".

The CBA contains long-wavelength components from deep and broad geologic structures extending far beyond the valley. These long-wavelength components, called the regional gravity, have been approximated by linear interpolation between CBA values at bedrock stations on opposite ends of the profiles. Where only one end of a profile was on bedrock, the regional value on the other end was assigned a quantity consistent with the regional trend of the valley. The regional gravity was subtracted from the CBA and the resulting residual anomaly profiles were used to model the valley. This regional separation technique is

only approximate. Some regional effects may still remain after the subtraction but the error is probably small compared to the large residual anomaly values of these profiles.

The CBA values and the straight line regional field for each profile is shown in the top portion of Figures 3 through 5. The residual gravity anomaly (interpolated at evenly spaced points) is shown by the crosses (x) in the second block of Figures 3 through 5.

4.2 DENSITY SELECTION

The construction of a geologic model from the residual anomaly, requires selection of density values representative of the alluvial fill and of the underlying rock. Since only very generalized density information is available, the geologic interpretation of the gravity data can be only a coarse approximation. Average in situ density of the fill material was measured between depths of 100 to 160 feet (30 to 49 m) in several shallow borings. The observed density range for the soil was 1.7 to 2.0 g/cm³. A larger density of 2.3 g/cm³ was used in the modeling process to approximate the expected overall alluvium density increase due to compaction with depth (compaction with depth and age is discussed by Woollard, 1962 and Grant and West, 1965).

The basement material underlying the Coal basin is thought to be the Paleozoic carbonate rocks which are found in the surrounding mountain ranges. Published values for carbonate rocks typically range between 2.6 and 2.8 g/cm³. The Paleozoic

carbonate rocks in Nevada are generally reported to be relatively high in density, on the order of 2.8 g/cm^3 . This value was selected to represent the density of the basement rock.

Relative to a given basement density, the calculated basin depth is inversely proportional to the density value assigned to the valley fill materials. A one percent change in the average alluvial fill density will result in a five percent change in the calculated fill thickness.

4.3 MODELING

An iterative computer program that calculates the gravitational field for two-dimensional models was used to approximate the thickness of alluvium beneath each profile. The cross-sectional models appear as a set of 0.5-km-wide blocks whose tops are at surface elevation and whose bottoms represent the alluvium-bedrock boundary. The elevations at the bottoms of the blocks were adjusted by iterative computation until the computed gravity anomaly for the valley fill differed by less than one milligal from the observed residual anomaly.

The gravity anomaly computed from the final model can be compared to the residual anomaly in the second block of Figures 3 through 5. The computed anomaly is shown as the solid line and the residual anomaly is shown by the crosses (x). The final calculated basin models are shown in the third block of Figures 3 through 5. The cross sections have a five times vertical exaggeration so that even gentle slopes appear steep. The lowest block shows a suggested geological interpretation.

All three gravity profiles indicate that Coal Valley is asymmetrical, with a dominant extremely steep fault between the outcrops and the deep basin with the largest of these being near the center of the topographic valley. On the southern profile, GC-5, a horst is indicated on the eastern side of the basin. The outcrop pattern (Figure 6) south of the profile can be construed to support this interpretation.

The calculated thickness of alluvium diminishes from approximately 6900 feet (2103 m) beneath profile WR-5 on the north to about 2900 feet (884 m) beneath profile GC-5 on the south. The deep basin floor calculates to be almost flat between profiles WR-5 and GC-4. The average rate of rise to the south between these profiles is about 50 feet per mile (9 m/km). This rate increases approximately ten times to more than 500 feet per mile (95 m/km) between profiles GC-4 and GC-5. Even this latter rate is insufficient to explain the proximity of the outcrops to the south. This may indicate that transverse faulting occurs south of profile GC-5.

5.0 CONCLUSION

There is a large well defined negative gravity anomaly associated with Coal Valley. An average density contrast of 0.50 g/cm^3 between the alluvium and bedrock was used to calculate the thickness of the valley fill material.

The gravity interpretation of Coal Valley indicates that the basin is asymmetrical with a major range bounding normal fault on the western side of the valley with a series of lesser faults in the eastern half of the valley. The primary graben block lies along the Golden Gate Range and is oriented NNE-SSW. Calculated depth ranges from 6900 feet (2103 m) beneath profile WR-5 and 2900 feet (884 m) beneath profile GC-5 near the south end.

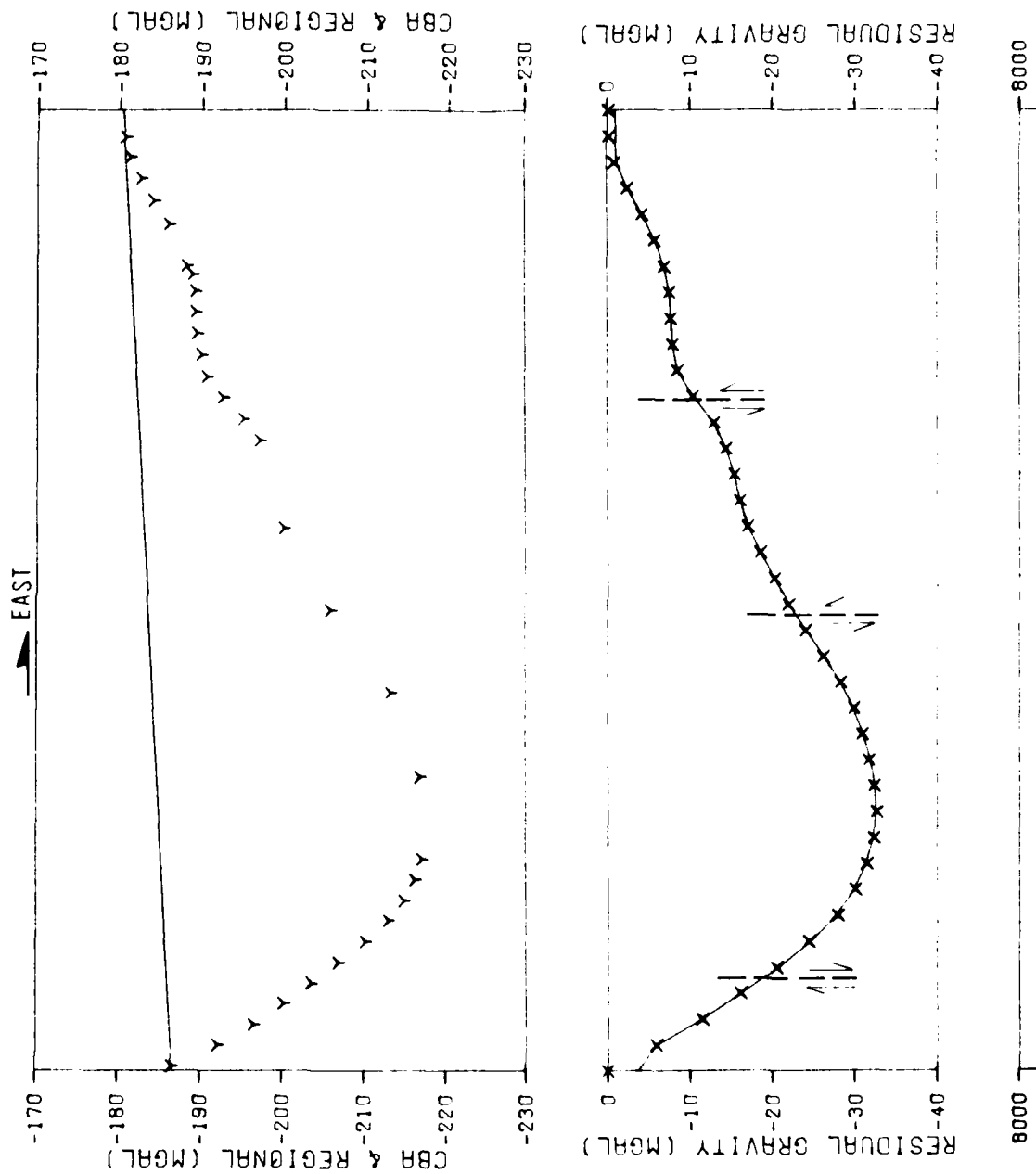
The calculated bedrock depths can only be approximations since little is known about the actual density distribution in and around the valley. Future studies that acquire better density data or actual depth to bedrock in deep parts of the valley can be used to refine the gravity interpretation.

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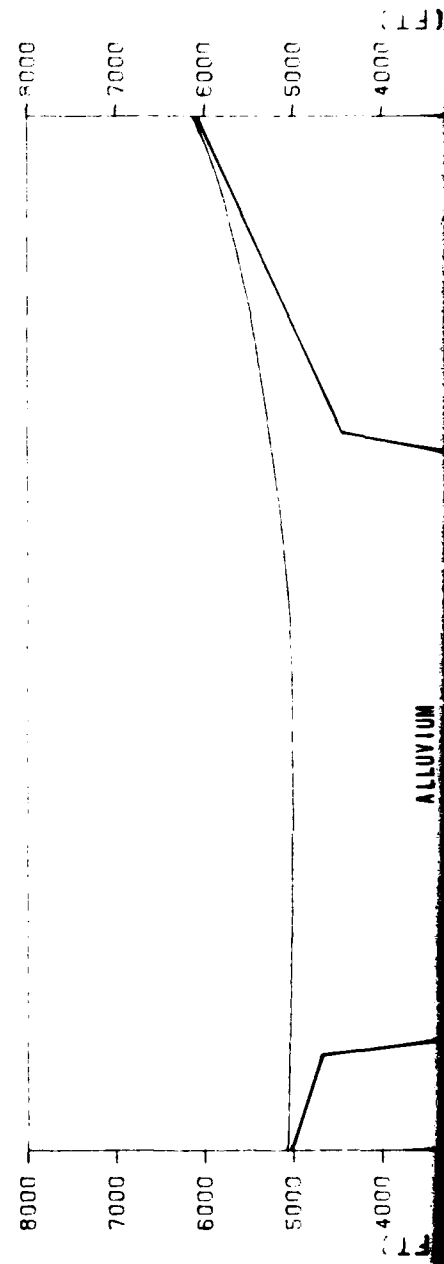
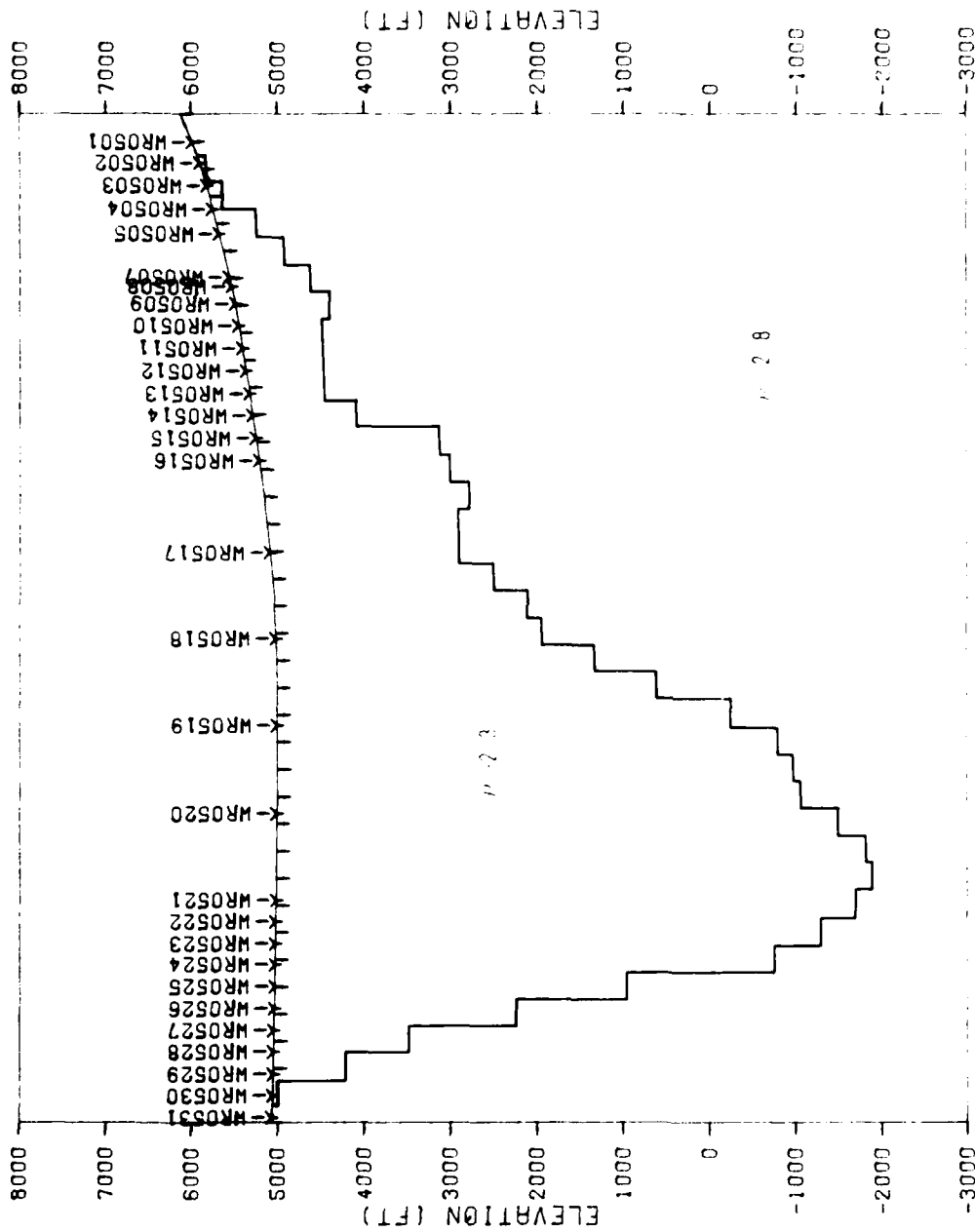
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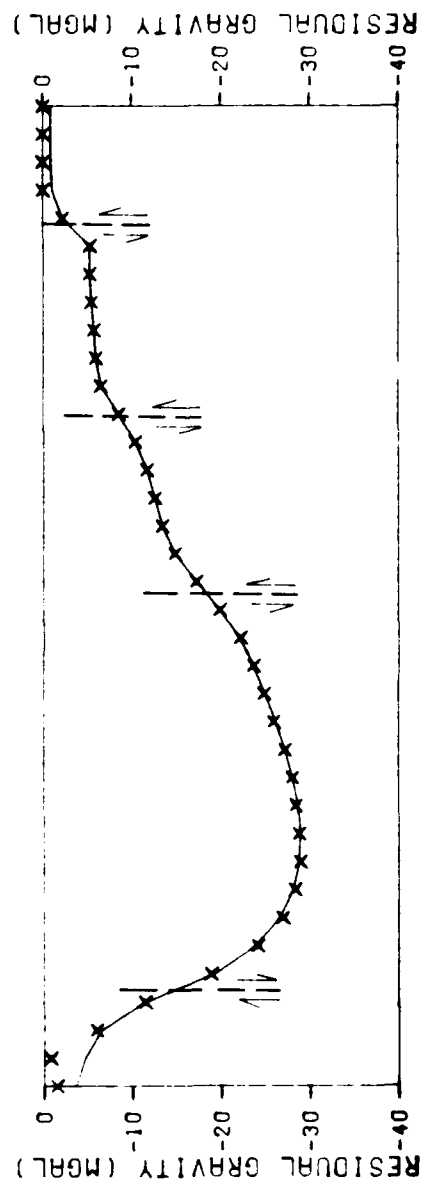
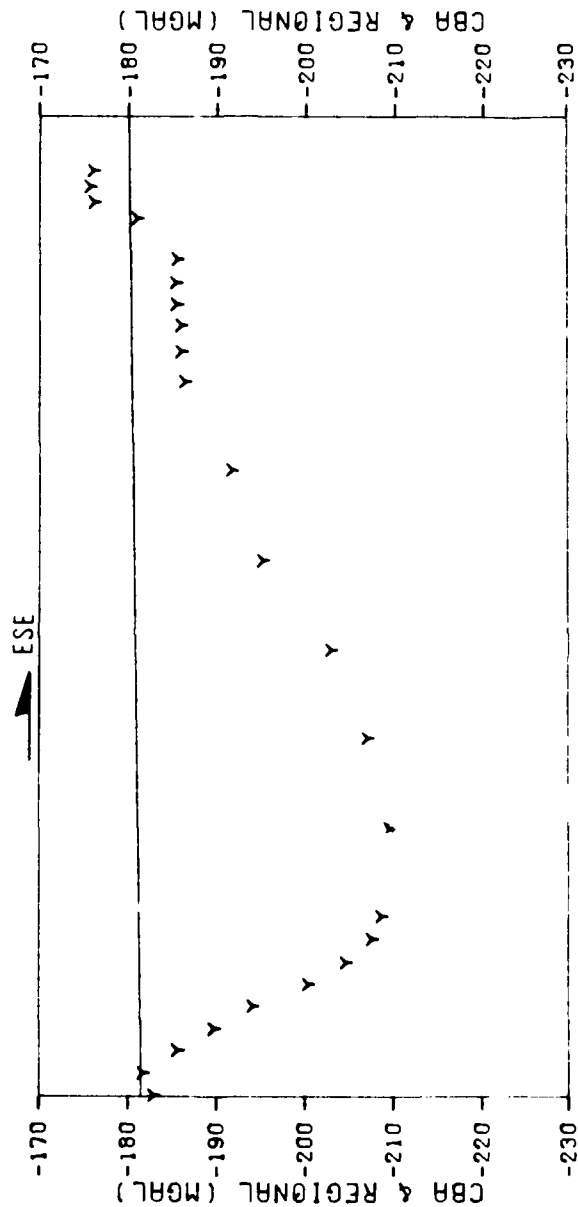


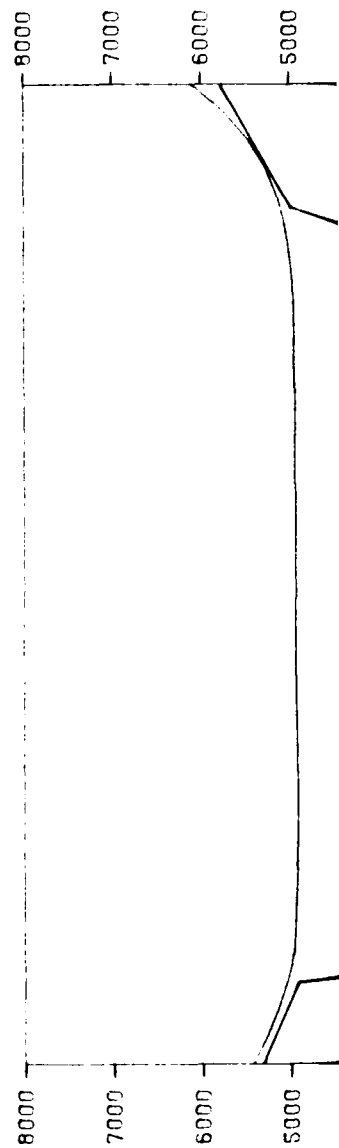
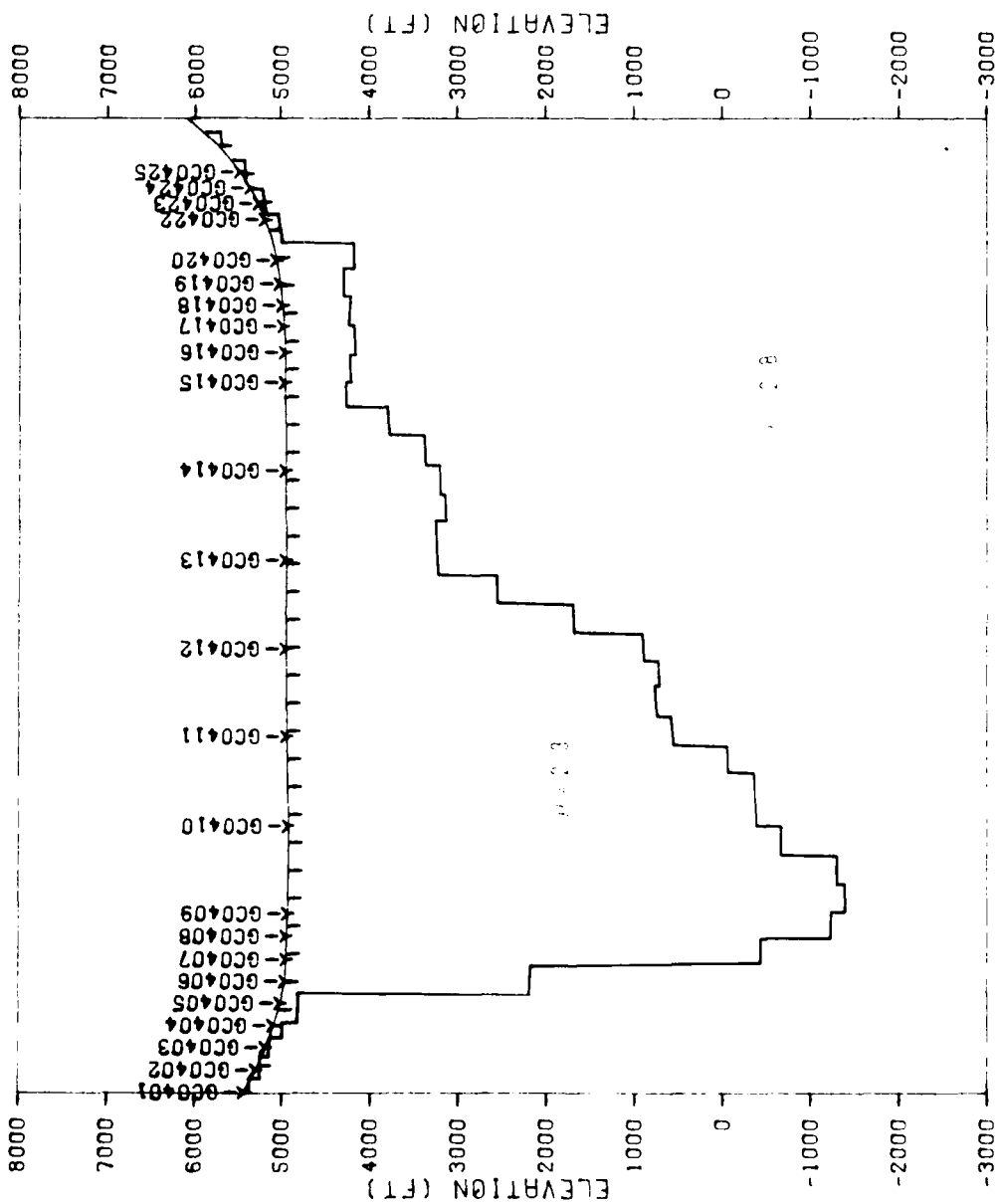
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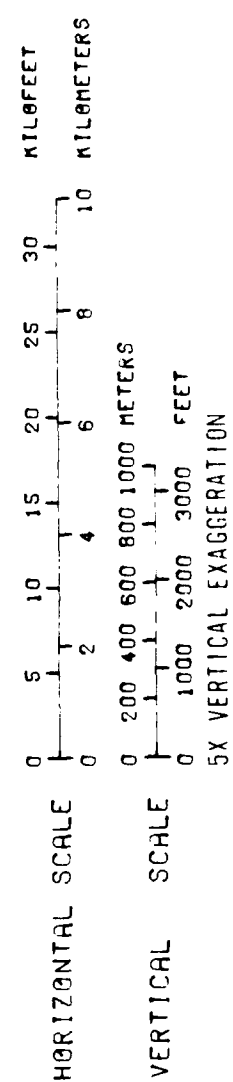
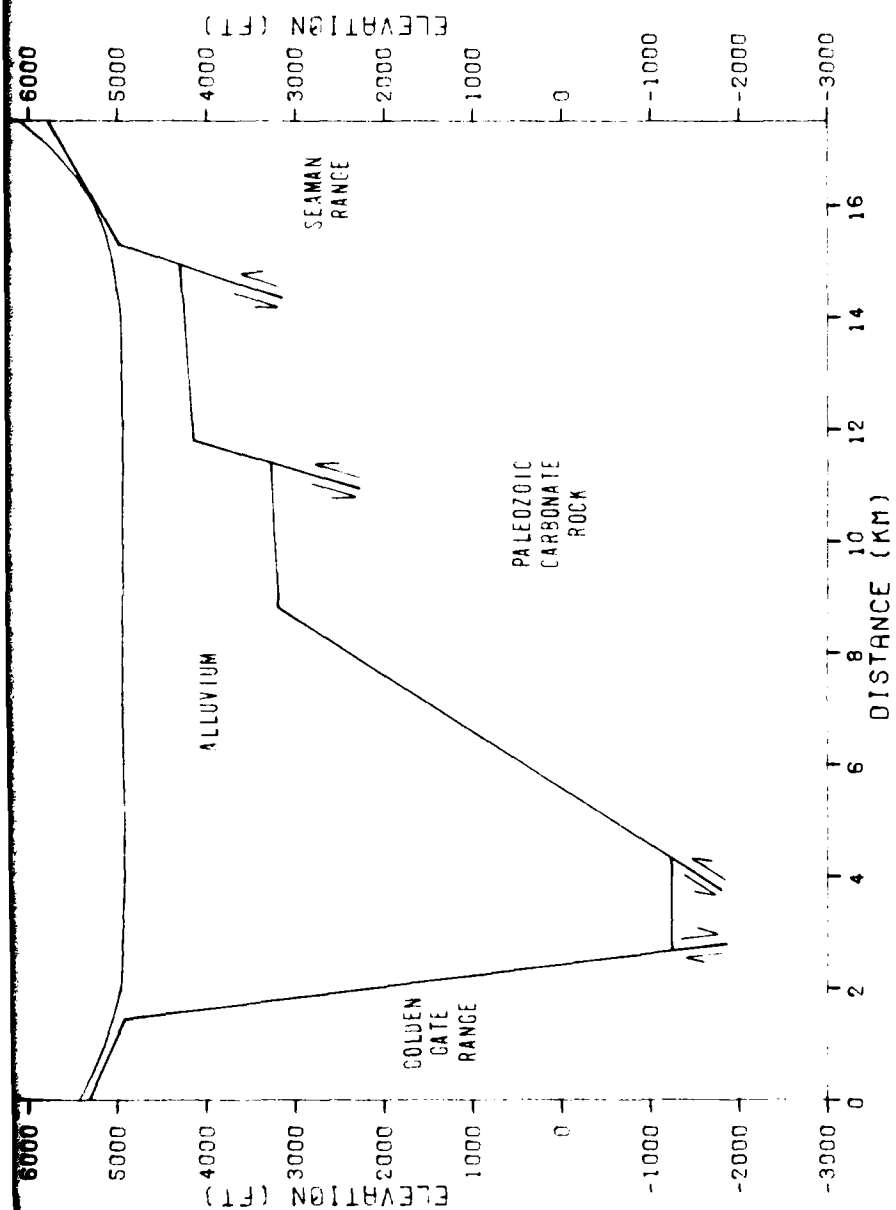
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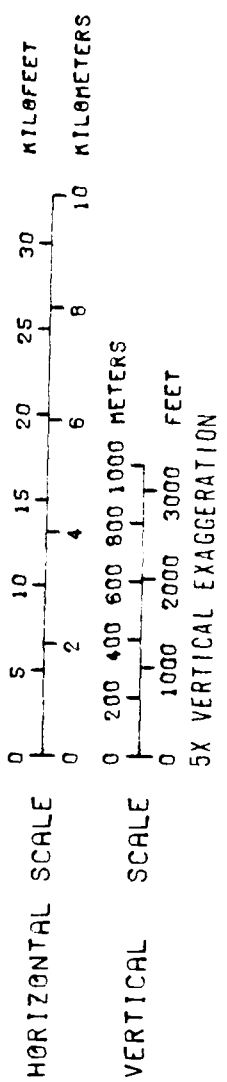
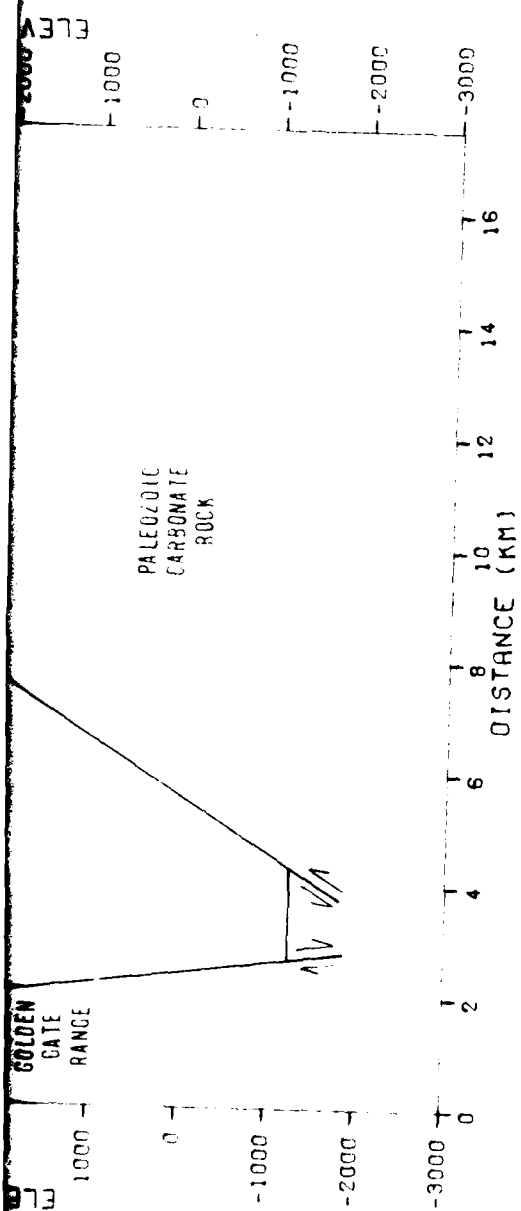






EXPLANATION

- BLOCK 1: GRAVITY REGIONAL
- BLOCK 2: RESIDUAL GRAVITY OBSERVED VALUES INTERPOLATED
- BLOCK 3: ELEVATION STATION ELEVATIONS AND IDENTIFICATION
- BLOCK 4: SUGGESTED GEOLOGICAL STRUCTURE
- GRAVITY INTERPRETED FAULT LOCATION

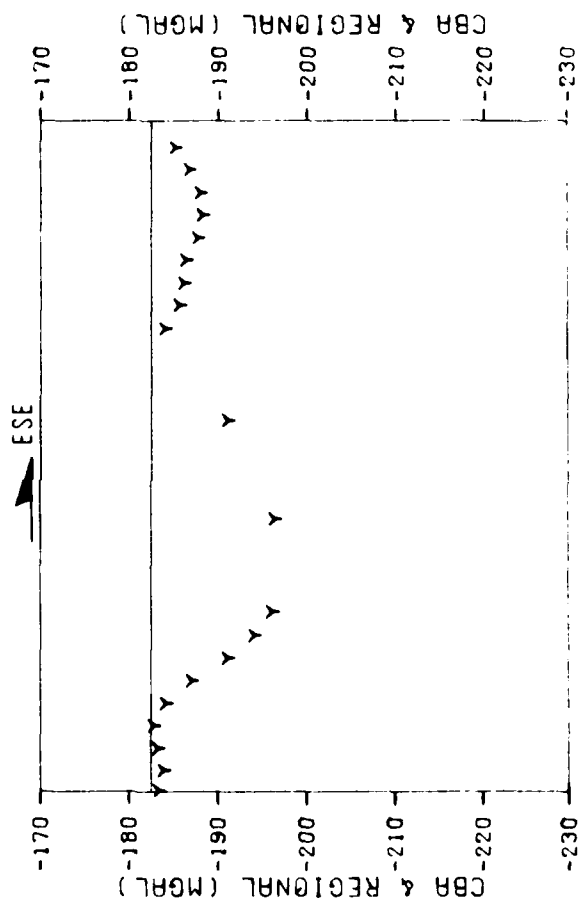
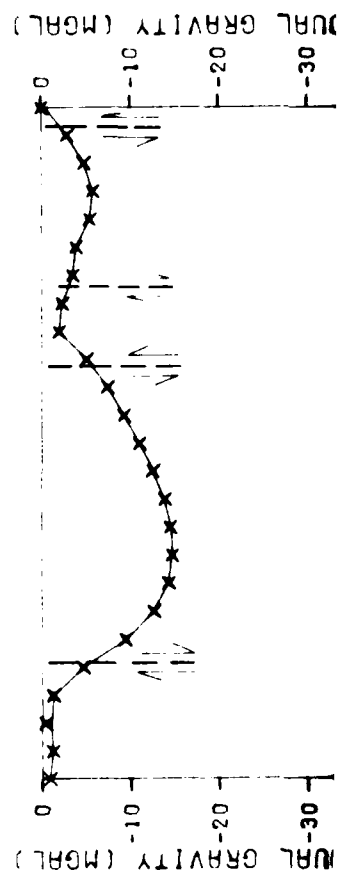


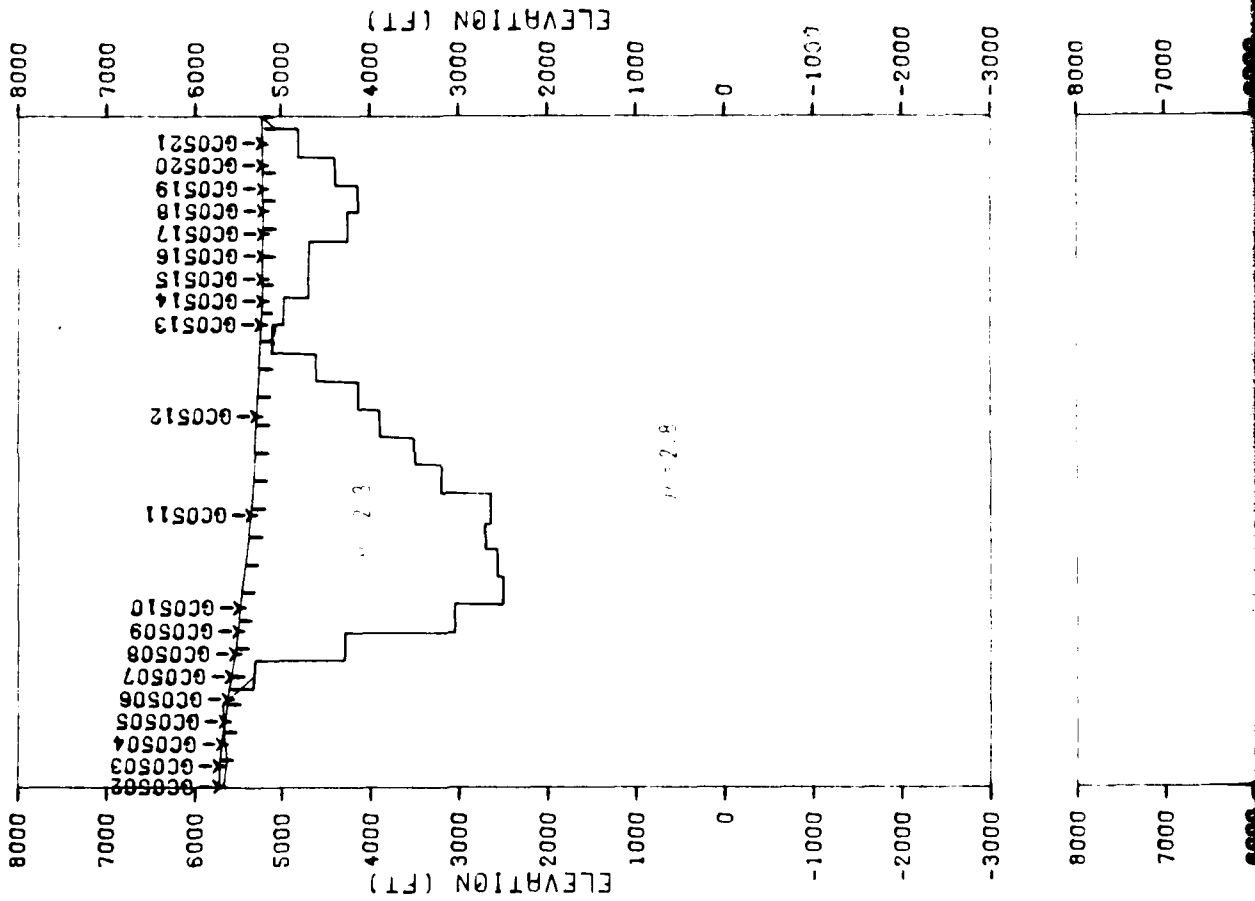
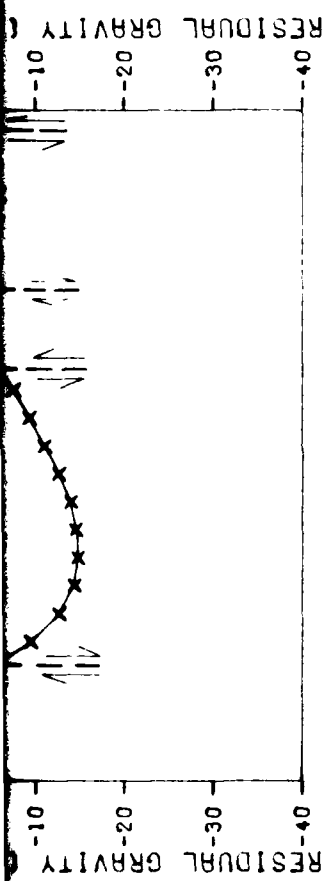
EXPLANATION

- BLOCK 1: CBA Y & REGIONAL
- BLOCK 2: REGIONAL GRAV OBSERVED VALUES INTERPOLATED & CALCULATED FROM MODEL
- BLOCK 3: ELEVATION STATION ELEVATIONS Y & IDENTIFICATION LOG LINE INTERPOLATED SURFACE ELEVATIONS MODEL OF BEDROCK SURFACE
- BLOCK 4: SUGGESTED GEOLOGICAL STRUCTURE DENSITY VALUES
- GRAVITY INTERPRETED FAULT LOCATION

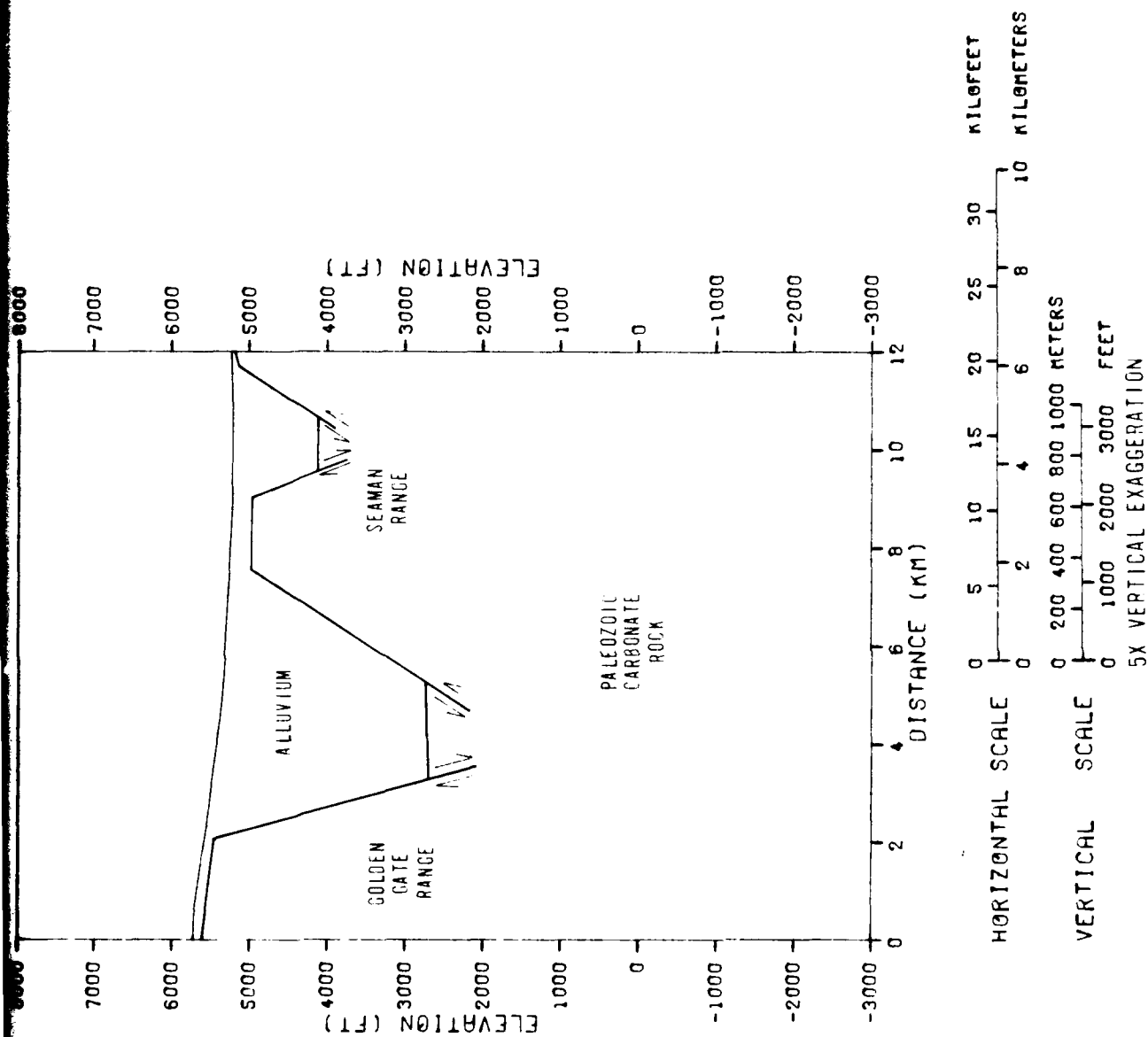
INTERPRETED GRAVITY PROFILE CO-4 COAL VALLEY NEVADA	
VI CON INVESTIGATION DEPARTMENT OF THE ARMY BMD	FIGURE 4
FUGRO NATIONAL, INC.	

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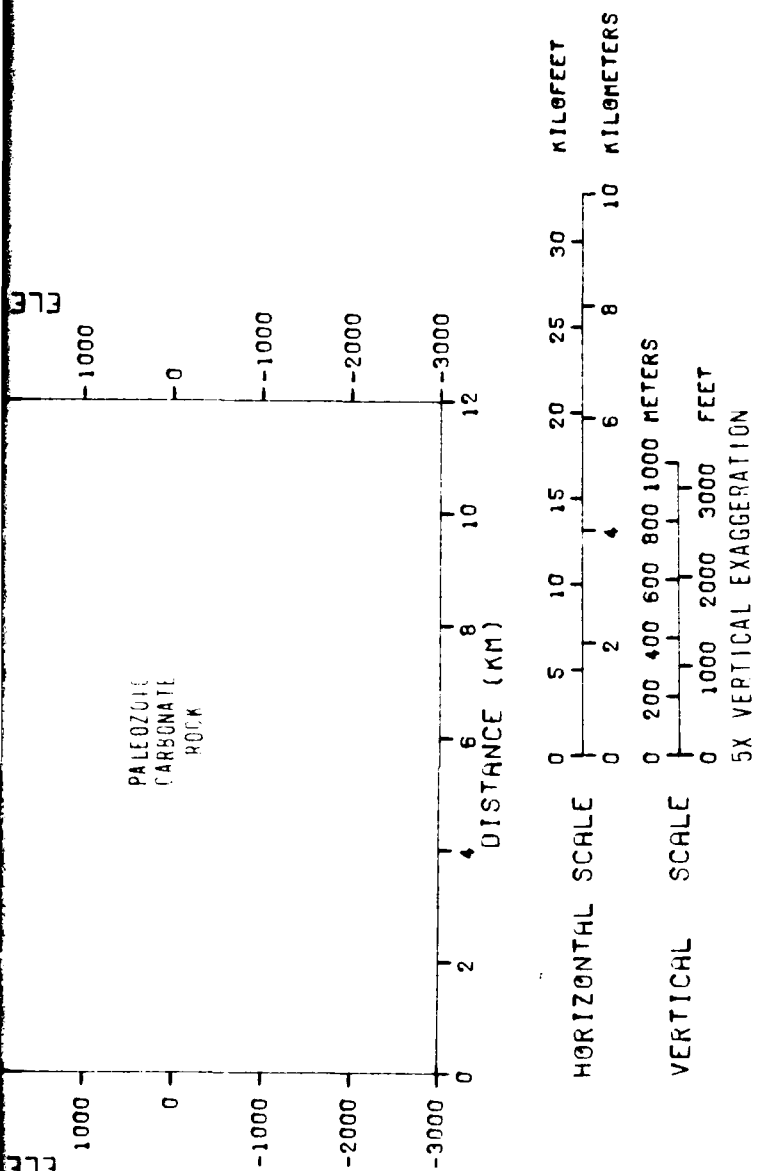


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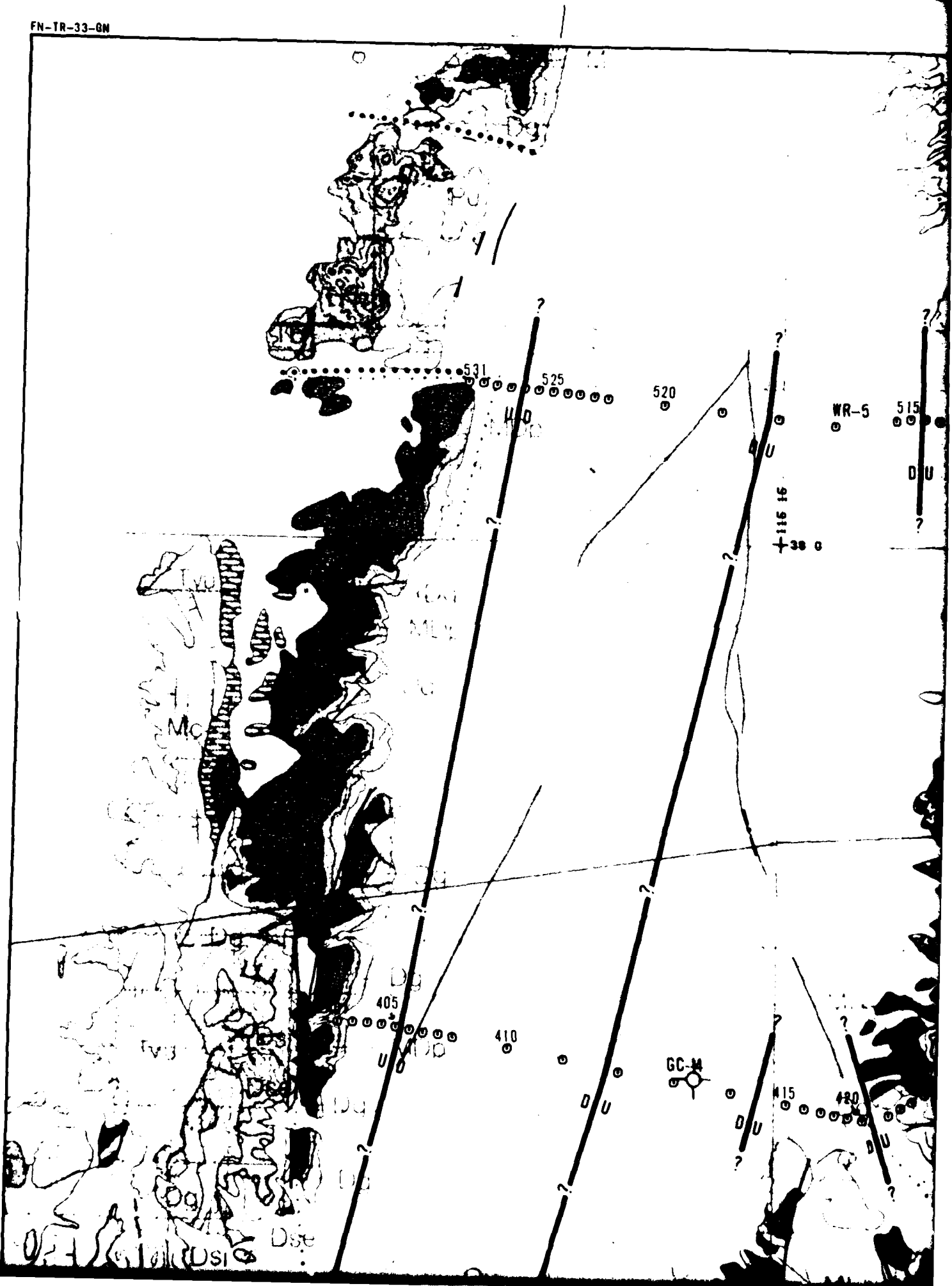
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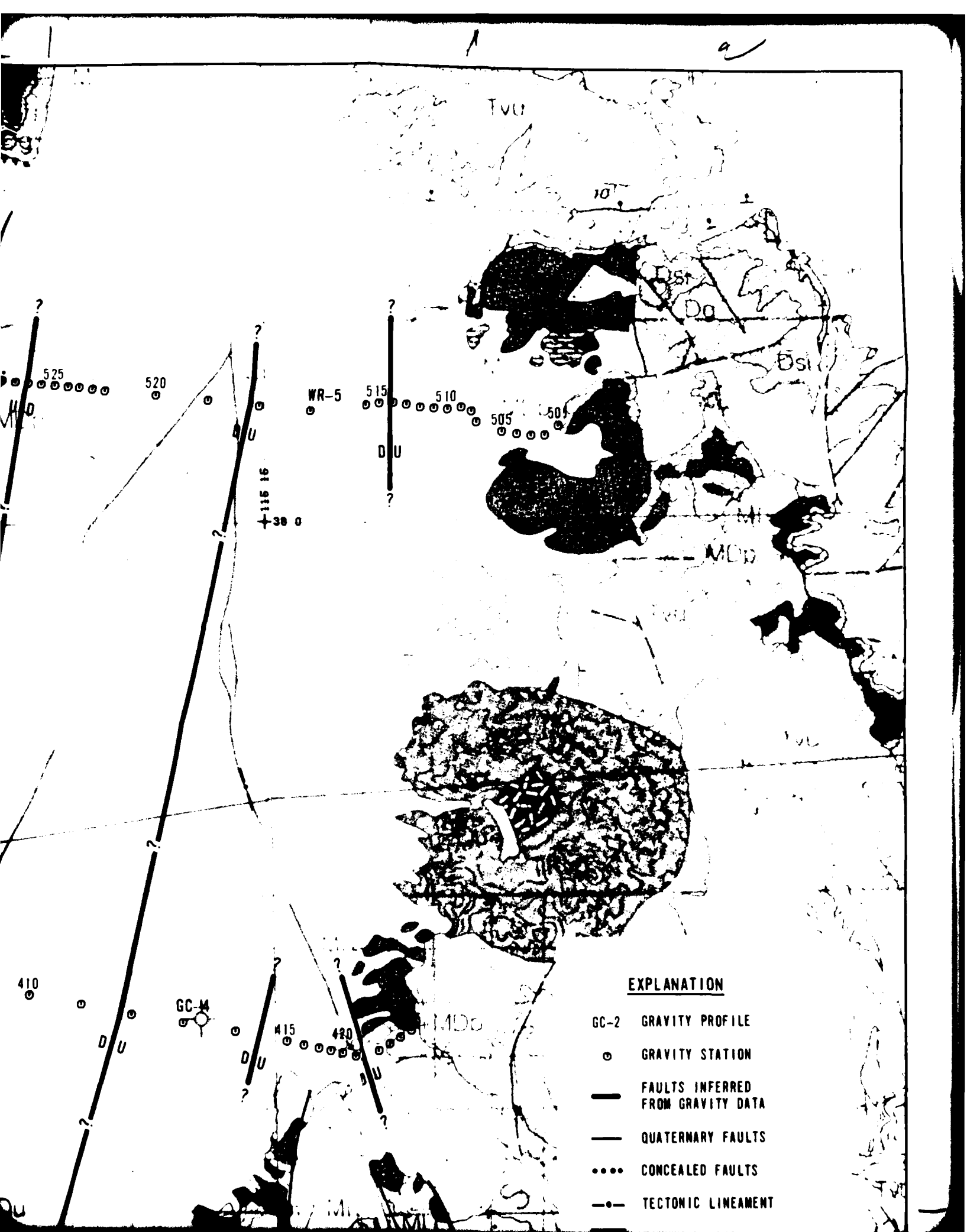
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- BLOCK 2 - RESIDUAL GRAV - OBSERVED VALUES INTERPOLATED
- BLOCK 3 - ELEVATION - STATION ELEVATIONS
- BLOCK 4 - IDENTIFICATION - GEO DATA
- BLOCK 5 - INTERPOLATED SURFACE ELEVATIONS



INTERPRETED GRAVITY PROFILE CO-5 COAL VALLEY NEVADA	
MOUNTAIN INVESTIGATION DEPARTMENT OF THE ARMY - BMD	FIGURE 5
FUGRO NATIONAL, INC.	

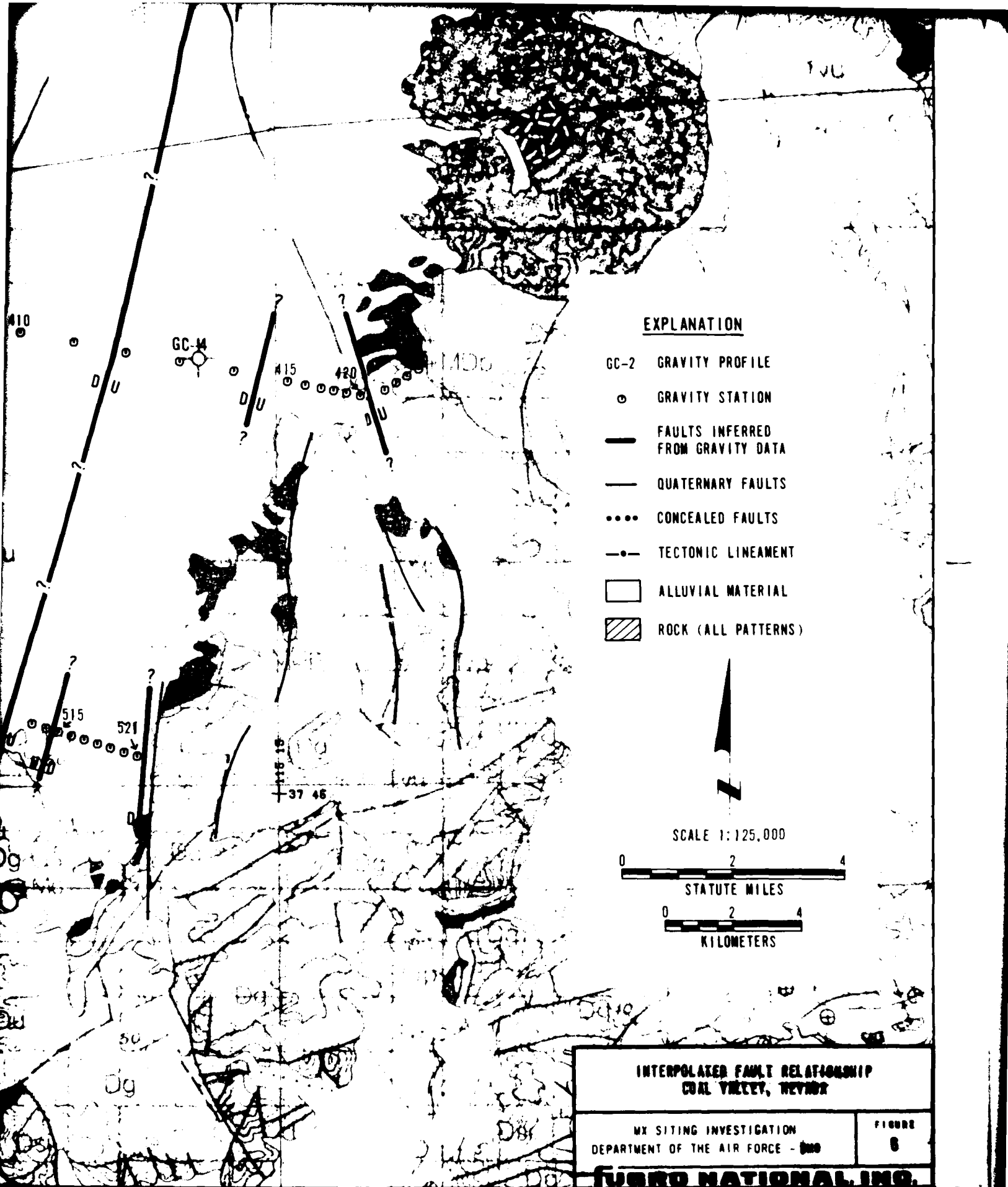
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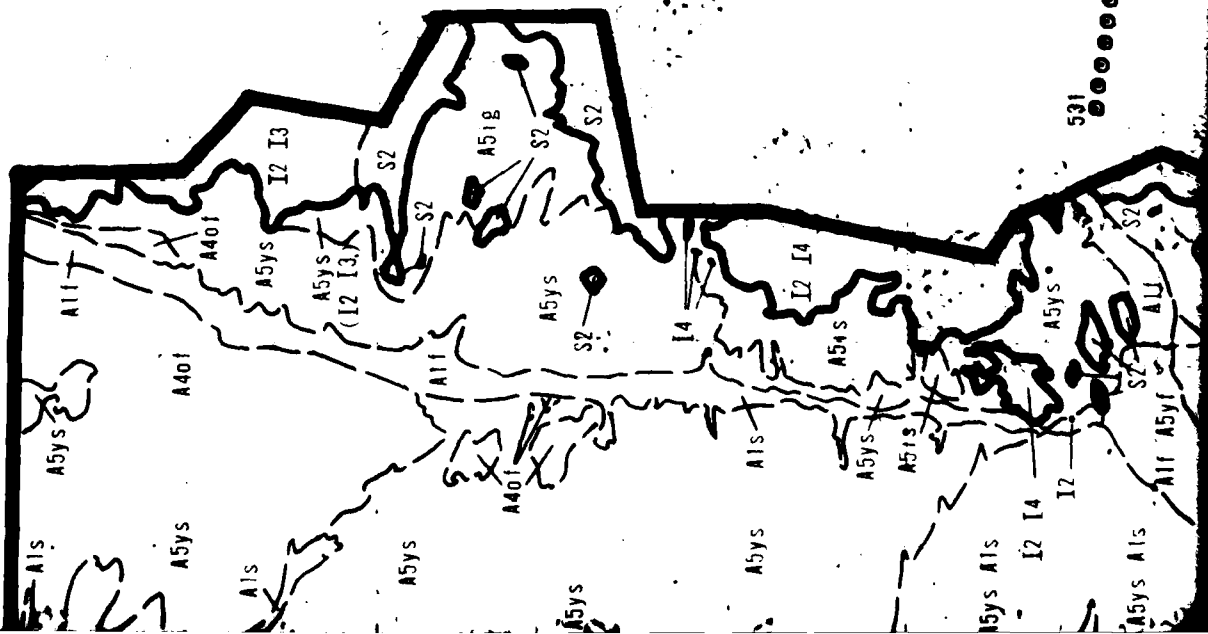
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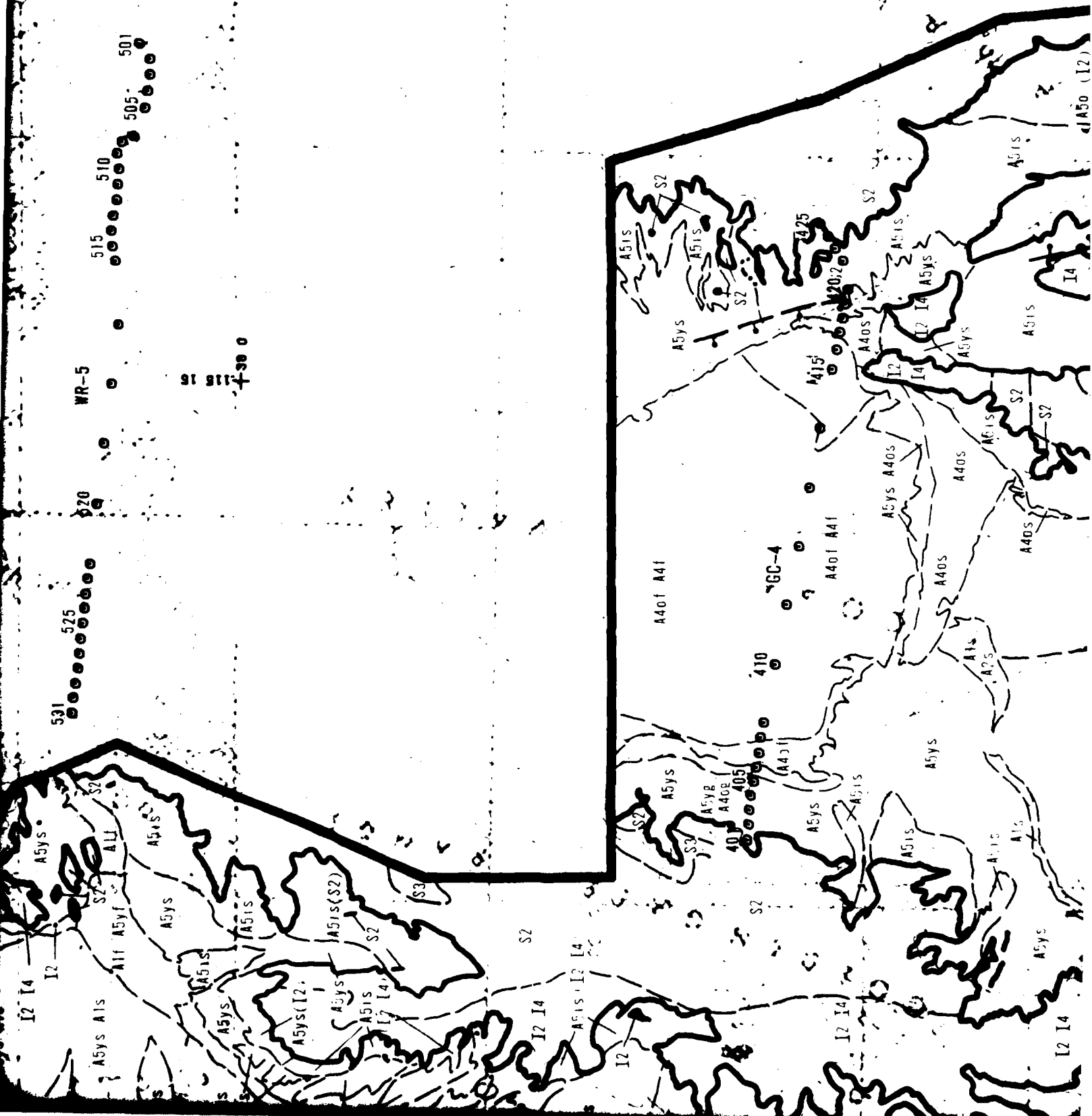


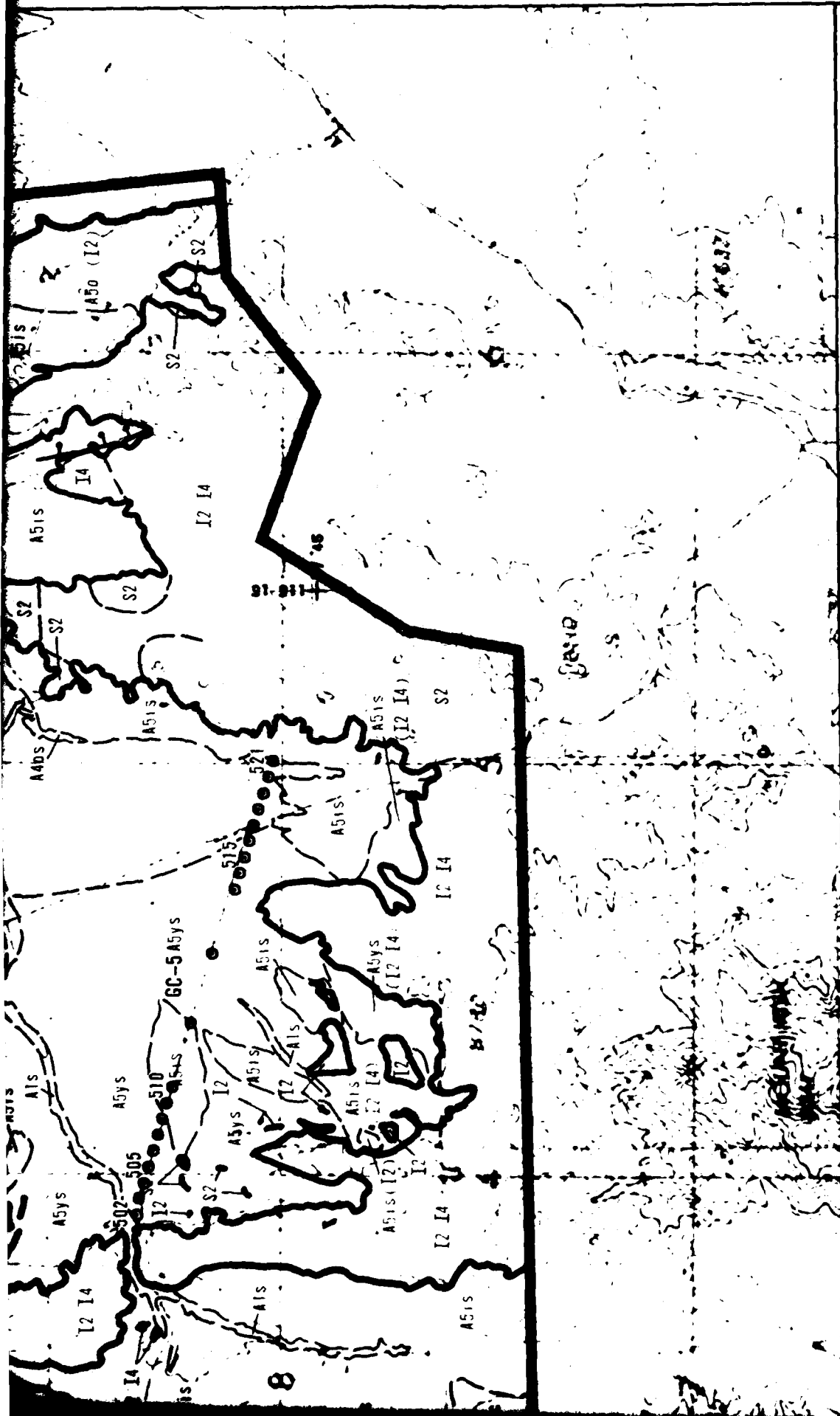
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EXPLANATION

SURFICIAL BASIN-FILL UNITS

- Modern stream channel and floodplain deposits of: All. clay (CL) and sandy silty sand (SM).
- Older stream channel and floodplain deposits in terraces composed of silty sand (SM)
- Active alluvial deposits of sandy silt (ML)

older stream channel and floodplain deposits in terraces composed of silty sand (SM).

Active playa deposits of sandy silt (ML)

Deposits - Inactive playa, older lake bed, and abandoned shoreline deposits of: ss. sand and gravelly sand (SP); and A4og. sandy gravel (GP)

Deposits - Active, younger alluvial fan deposits of: A5yl. sandy silt (ML); silty sand and gravelly sand (SM); and A5yg. weakly cemented sandy gravel (GM).

Deposits - Inactive, intermediate-age alluvial fan deposits of: silty sand and gravelly sand (SM); and A5ig. sandy gravel (GM)

Deposits - Older, highly eroded alluvial fan deposits of moderately cemented sand and gravel with more than 30 percent boulders and cobbles

ROCK UNITS

Basalt, and andesite

and ignimbrite

Locally cherty, with interbedded shale and sandstone

Sandstone and sandstone

These symbols indicate a mixture of either surficial basin-fill or rock units

surface unit at shallow depth.

ROCK UNITS

dacite, and andesite

st, and ignimbrite

locally cherty, with interbedded shale and sandstone

limestone and sandstone

unit symbols indicates a mixture of either surficial basin-fill or rock units

es surface unit at shallow depth.

SYMBOLS

surficial basin-fill units

al basin-fill or rock units

rupture of faults offsetting surficial basin-fill deposits, ball on downthrown side

ertain only to the upper several feet of soil. Due to variability of surficial deposits
tion unit descriptions refer to the predominant soil types. Varying amounts of other soil
in each geologic unit

ic data stations is presented in Volume VI, Drawing 1. A tabulation of all station data
en of all geologic units is included in Volume VI, Section 1.0

ed rock from: Kleinhampl and Ziony (1967), Tschanz and Pampeyan (1970)



SCALE 1:125,000

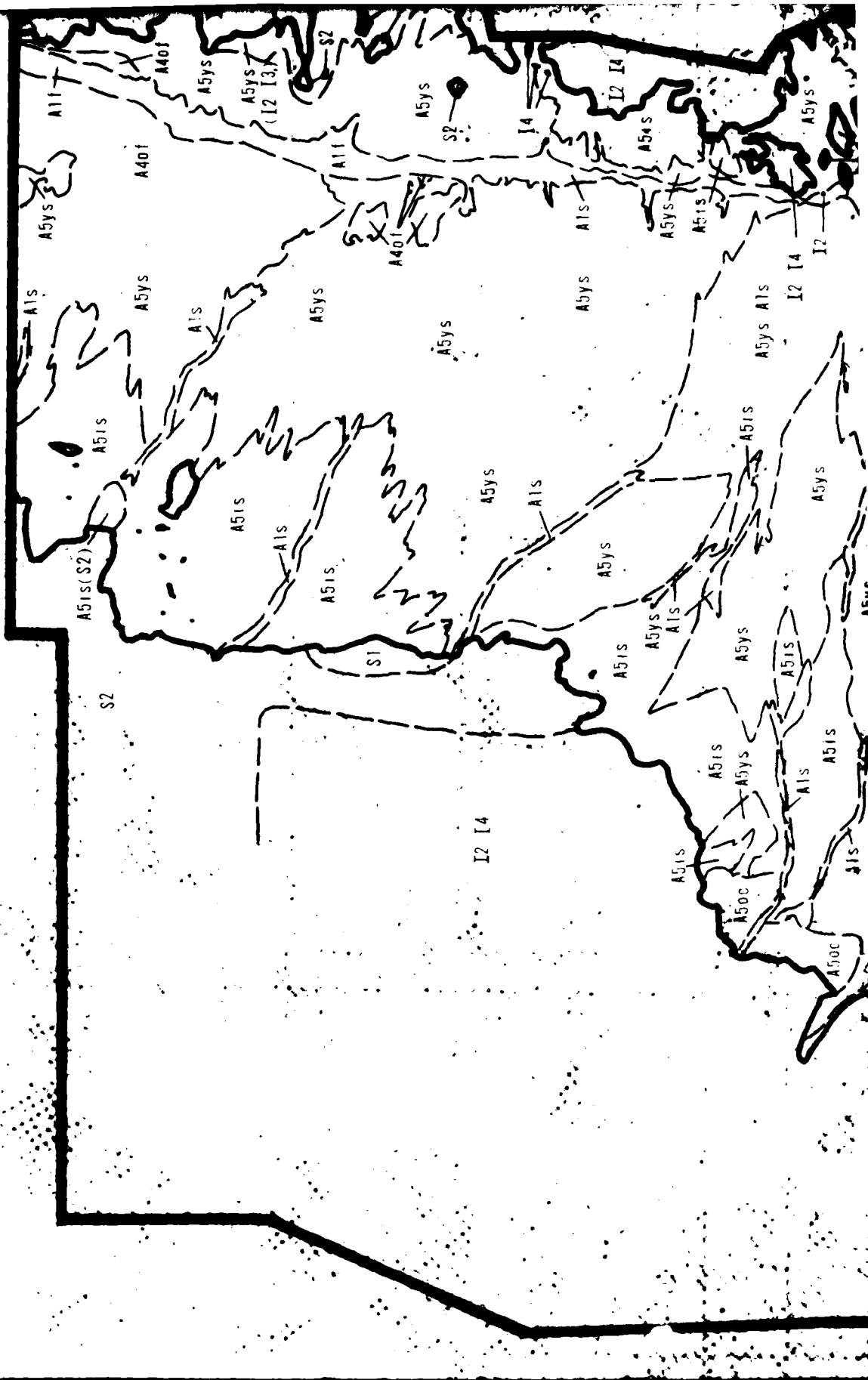


STATUTE MILES

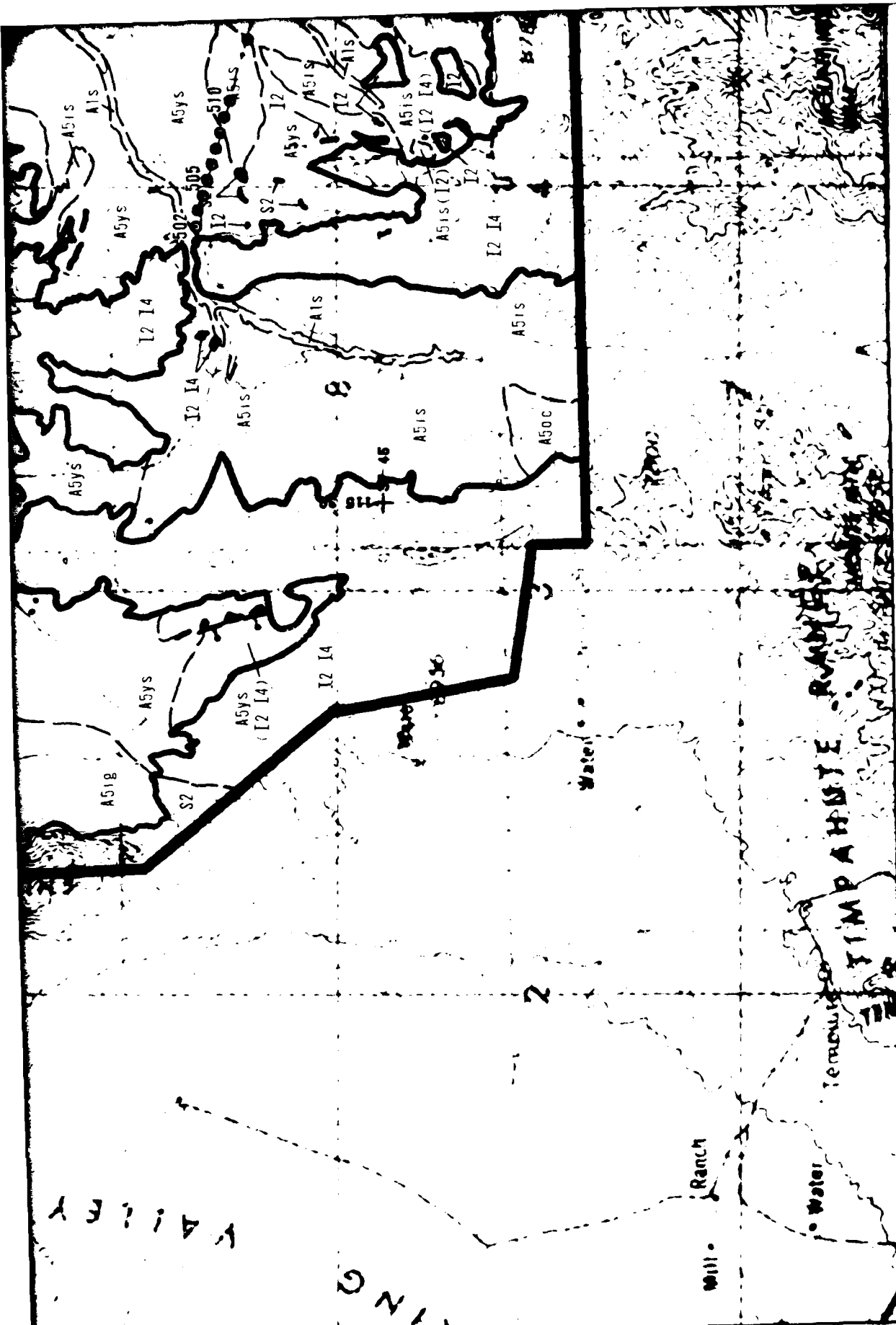


KILOMETERS

30 MAY 80



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EXPLANATION

SURFICIAL BASIN-FILL UNITS

Younger Alluvial Deposits - Modern stream channel and floodplain deposit silt (ML) and AIs, silty sand (SM).

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AIS

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Older Fluvial Deposits - Older stream channel and floodplain deposits

A1f	Younger Alluvial Deposits - Modern stream channel and floodplain silt (ML) and A1s, silty sand (SM).
A1s	
A2s	Older Fluvial Deposits - Older stream channel and floodplain deposits
A4f	Younger Playa Deposits - Active playa deposits of sandy silt (ML)
A4of	Older Playa and Lacustrine Deposits - Inactive playa, older lake beds A4of, sandy silt (ML); A4os, sand and gravelly sand (SP); and A4og
A4os	
A4og	
A5yf	Younger Alluvial Fan Deposits - Active, younger alluvial fan deposits A5ys, weakly cemented silty sand and gravelly sand (SM); and A5yg.
A5ys	
A5yg	
A5is	Intermediate Alluvial Fan Deposits - Inactive, intermediate-age alluvial fans A5is, moderately cemented silty sand and gravelly sand (SM); and
A5ig	
A5oc	Older Alluvial Fan Deposits - Older, highly eroded alluvial fan deposits gravelly sand with greater than 30 percent boulders and cobbles

ROCK UNITS

Igneous (I)	
I1	Granite
I2	Rhyolite, quartz latite, dacite, and andesite
I3	Basalt
I4	Tuff, tuffaceous sediment, and ignimbrite
Sedimentary (S)	
S1	Orthoquartzite
S2	Limestone and dolomite, locally cherty, with interbedded shale and
S3	Shale, with interbedded limestone and sandstone

A5ys A5is Combination of geologic unit symbols indicates a mixture of either inseparable at map scale

A5is(I2) Parenthetic unit underlines surface unit at shallow depth.

A50C Older Alluvial Fan Deposits - Older, highly eroded alluvial fan deposits consisting of gravelly sand with greater than 30 percent boulders and cobbles

ROCK UNITS

Igneous (I)

I1 Granite

I2 Rhyolite, quartz latite, dacite, and andesite

I3 Basalt

I4 Tuff, tuffaceous sediment, and ignimbrite

Sedimentary (S)

S1 Orthoquartzite

S2 Limestone and dolomite, locally cherty, with interbedded shale and sandstone


S3 Shale, with interbedded limestone and sandstone


A5ys/A5is Combination of geologic unit symbols indicates a mixture of either surficial basin-fill or surficial basin-fill units inseparable at map scale


A5is(I2) Parentetic unit underlies surface unit at shallow depth.

SYMBOLS

 Contact between rock and surficial basin-fill units

 Contact between surficial basin-fill or rock units

 Fault, trace of surface rupture of faults offsetting surficial basin-fill units

 Gravity Station

- NOTES**
1. Surficial basin-fill units pertain only to the upper several feet of soil and scale of map presentation. Unit descriptions refer to the predominant sediment types can be expected within each geologic unit.
 2. The distribution of geologic data stations is presented in Volume VI. Drawings and generalized description of all geologic units is included in Volume VII.
 3. Geology in areas of exposed rock from: Kleinhampt and Ziony (1967), Tschanz

GRAVITY STATION LOCATION MAP COAL VALLEY, NEVADA	
MX SITING INVESTIGATION DEPARTMENT OF THE AIR FORCE -DMO	DRAWING 1

FUERO NATIONAL, INC.

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FN-TR-33-CL

APPENDIX A1.0

GENERAL PRINCIPLES OF THE
GRAVITY EXPLORATION METHOD

A1.0 GENERAL PRINCIPLES OF THE GRAVITY
 EXPLORATION METHOD

A1.1 GENERAL

A gravity survey involves measurement of differences in the gravitational field between various points on the earth's surface. The gravitational field values being measured are the same as those influencing all objects on the surface of the earth. They are generally associated with the force which causes a 1 gm mass to be accelerated at 980 cm/sec^2 . This force is normally referred to as a 1 g force.

Even though in many applications the gravitational field at the earth's surface is assumed to be constant, small but distinguishable differences in gravity occur from point to point. In a gravity survey, the variations are measured in terms of milligals. A milligal is equal to $0.001 \text{ cm/second}^2$ or 0.00000102 g . The differences in gravity are caused by geometrical effects, such as differences in elevation and latitude, and by lateral variations in density within the earth. The lateral density variations are a result of changes in geologic conditions. For measurements at the surface of the earth, the largest factor influencing the pull of gravity is the density of all materials between the center of the earth and the point of measurement.

To detect changes produced by differing geological conditions, it is necessary to detect differences in the gravitational field as small as a few milligals. To recognize changes due to

geological conditions, the measurements are "corrected" to account for changes due to differences in elevation and latitude.

Given this background, the basic concept of the gravitational exploration method, the anomaly, can be introduced. If, instead of being an oblate spheroid characterized by complex density variations, the earth were made up of concentric, homogeneous shells, the gravitational field would be the same at all points on the surface of the earth. The complexities in the earth's shape and material distribution are the reason that the pull of gravity is not the same from place to place. A difference in gravity between two points which is not caused by the effects of known geometrical differences, such as in elevation, latitude, and surrounding terrain, is referred to as an "anomaly."

An anomaly reflects lateral differences in material densities. The gravitational attraction is smaller at a place underlain by relatively low density material than it is at a place underlain by a relatively high density material. The term "negative gravity anomaly" describes a situation in which the pull of gravity within a prescribed area is small compared to the area surrounding it. Low-density alluvial deposits in basins such as those in the Nevada-Utah region produce negative gravity anomalies in relation to the gravity values in the surrounding mountains which are formed by more dense rocks.

The objective of gravity exploration is to deduce the variations in geologic conditions that produce the gravity anomalies identified during a gravity survey.

A1.2 INSTRUMENTS

The sensing element of a LaCoste and Romberg gravimeter is a mass suspended by a zero-length spring. Deflections of the mass from a null position are proportional to changes in gravitational attraction. These instruments are sealed and compensated for atmospheric pressure changes. They are maintained at a constant temperature by an internal heater element and thermostat. The absolute value of gravity is not measured directly by a gravimeter. It measures relative values of gravity between one point and the next. Gravitational differences as small as 0.01 milligal can be measured.

A1.3 FIELD PROCEDURES

The gravimeter readings were calibrated in terms of absolute gravity by taking readings twice daily at nearby USGS gravity base stations. Gravimeter readings fluctuate because of small time-related deviations due to the effect of earth tides and instrument drift. Field readings were corrected to account for these deviations. The magnitude of the tidal correction was calculated using an equation suggested by Goguel (1954):

$$C = P + N \cos \phi (\cos \phi + \sin \phi) + S \cos \phi (\cos \phi - \sin \phi)$$

where C is the tidal correction factor, P, N, and S are time-related variables, and ϕ is the latitude of the observation point. Tables giving the values of P, N, and S are published annually by the European Association of Exploration Geophysicists.

The meter drift correction was based on readings taken at a designated base station at the start and end of each day. Any difference between these two readings after they were corrected for tidal effects was considered to have been the result of instrumental drift. It was assumed that this drift occurred at a uniform rate between the two readings. Corrections for drift were typically only a few hundredths of a milligal. Readings corrected for tidal effects and instrumental drift represented the observed gravity at each station. The observed gravity values represent the total gravitational pull of the entire earth at the measurement stations.

A1.4 DATA REDUCTION

Several corrections or reductions are made to the observed gravity to isolate the portion of the gravitational pull which is due to the crustal and near-surface materials. The gravity remaining after these reductions is called the "Bouguer Anomaly." Bouguer Anomaly values are the basis for geologic interpretation. To obtain the Bouguer Anomaly, the observed gravity is adjusted to the value it would have had if it had been measured at the geoid, a theoretically defined surface which approximates the surface of mean sea level. The difference between the "adjusted" observed gravity and the gravity at the geoid calculated for a theoretically homogeneous earth is the Bouguer Anomaly.

Four separate reductions, to account for four geometrical effects, are made to the observed gravity at each station to arrive at its Bouguer Anomaly value.

a. Free-Air Effect: Gravitational attraction varies inversely as the square of the distance from the center of the earth. Thus corrections must be applied for elevation. Observed gravity levels are corrected for elevation using the normal vertical gradient of:

$$FA = -0.09406 \text{ mg/ft } (-0.3086 \text{ milligals/meter})$$

where FA is the free-air effect (the rate of change of gravity with distance from the center of the earth). The free-air correction is positive in sign since the correction is opposite the effect.

b. Bouguer Effect: Like the free-air effect, the Bouguer effect is a function of the elevation of the station, but it considers the influence of a slab of earth materials between the observation point on the surface of the earth and the corresponding point on the geoid (sea level). Normal practice, which is to assume that the density of the slab is 2.67 grams per cubic centimeter was followed in these studies. The Bouguer correction (B_C), which is opposite in sign to the free-air correction, was defined according to the following formula.

$$B_C = 0.01276 (2.67) h_f \text{ (milligals per foot)}$$

$$B_C = 0.04185 (2.67) h_m \text{ (milligals per meter)}$$

where h_f is the height above sea level in feet and h_m is the height in meters.

c. Latitude Effect: Points at different latitudes will have different "gravities" for two reasons. The earth (and the geoid) is spheroidal, or flattened at the poles. Since points at higher latitudes are closer to the center of the earth than points near the equator, the gravity at the higher latitudes is larger. As the earth spins, the centrifugal acceleration causes a slight decrease in gravity. At the higher latitudes where the earth's radii are smaller, the centrifugal acceleration diminishes. The gravity formula for the Geodetic Reference System, 1967, gives the theoretical value of gravity at the geoid as a function of latitude. It is:

$$g = 978.0381 (1 + 0.0053204 \sin^2 \phi - 0.0000058 \sin^2 2\phi) \text{ gals}$$
where g is the theoretical acceleration of gravity and ϕ is the latitude in degrees. The positive term accounts for the spheroidal shape of the earth. The negative term adjusts for the centrifugal acceleration.

The previous two corrections (free air and Bouguer) have adjusted the observed gravity to the value it would have had at the geoid (sea level). The theoretical value at the geoid for the latitude of the station is then subtracted from the adjusted observed gravity. The remainder is called the Simple Bouguer Anomaly (SBA). Most of this gravity represents the effect of material beneath the station, but part of it may be due to irregularities in terrain (upper part of the Bouguer slab) away from the station.

d. Terrain Effect: Topographic relief around the station has a negative effect on the gravitational force at the station. A nearby hill has upward gravitational pull and a nearby valley contributes less downward attraction than a nearby material would have. Therefore, the corrections are always positive. Corrections are made to the SBA when the terrain effects were 0.1 milligal or larger. Terrain corrected Bouguer values are called the Complete Bouguer Anomaly (CBA). When the CBA is obtained, the reduction of gravity at individual measurement points (stations) is complete.

A1.5 INTERPRETATION

The first step in interpretation is to separate the portion of the CBA that might be caused by the lightweight, basin-fill material overlying the heavier bedrock material which forms the surrounding mountains and presumably the basin floor. Since the valley-fill sediments are absent at the stations read in the mountains, the CBA values at these bedrock stations are used as the basis for constructing a regional field over the valley. A regional field is an estimation of the values the CBA would have had if the light weight sediments (the anomaly) had not been there.

The difference between the CBA and the regional field is called the "residual" field or residual anomaly. The residual field is the interpreter's estimation of the gravitational effect of the geologic anomaly. The zero value of the residual anomaly is not exactly at the rock outcrop line but at some

distance on the "rock" side of the contact. The reason for this is found in the explanation of the terrain effect. There is a component of gravitational attraction from material which is not directly beneath a point.

If the "regional" is well chosen, the magnitude of the residual anomaly is a function of the thickness of the anomalous (fill) material and the density contrast. The density contrast is the difference in density between the alluvial and bedrock material. If this contrast were known, an accurate calculation of the thickness could be made. In most cases, the densities are not well known and they also vary within the study area. In these cases, it is necessary to use typical densities for materials similar to those in the study area.

If the selected average density contrast is smaller than the actual density contrast, the computed depth to bedrock will be greater than the actual depth and vice-versa. The computed depth is inversely proportional to the density contrast. A ten percent error in density contrast produces a ten percent error in computed depth. An iterative computer program is used to calculate a subsurface model which will yield a gravitational field to match (approximately) the residual gravity anomaly.

FN-TR-33-CL

APPENDIX A2.0

COAL VALLEY, NEVADA

GRAVITY DATA

COAL VALLEY GRAVITY DATA

PROFILE GC-4

STATION IDENT.	LAT. DEG MIN	LONG. DEG MIN	ELEV. +CODE	TER-COR. IN/OUT	NORTH UTM	EAST UTM	UNSV GRAV	THEO GRAV	FAA	GRA +1000
GC0401	375267	1152334	5425R	0	357419328	64168146929198134	-152	81672		
GC0402	375266	1152305	5285R	0	466419327	64211147781198137	-619	81622		
GC0403	375265	1152277	5177R	0	298419326	64252148202198135	-1206	81433		
GC0404	375263	1152250	5090R	0	241419323	64292148372198132	-1658	81022		
GC0405	375259	1152223	5016R	0	215419316	64331148393198127	-2528	80570		
GC0406	375255	1152197	4953R	0	196419304	64370148156198121	-3347	79954		
GC0407	375251	1152171	4944R	0	175419302	64408147805198115	-3782	79530		
GC0408	375248	1152142	4945R	0	154419298	64450147526198110	-4040	79240		
GC0409	375244	1152115	4927R	0	144419291	64490147527198105	-4205	79132		
GC0410	375228	1152010	4918R	0	114419264	64645147494198081	-4303	79037		
GC0411	375212	1151902	4939R	0	91419237	64804147621198058	-3953	79292		
GC0412	375194	1151797	4942R	0	87419207	64958147487198031	-3531	79699		
GC0413	375179	1151690	4945R	0	86419182	65115148731198009	-2746	80476		
GC0414	375164	1151582	4948R	0	87419157	65274149038197988	-2384	80827		
GC0415	375147	1151476	4954R	0	97419129	65430149495197963	-1846	81354		
GC0416	375141	1151441	4956R	0	103419118	65482149510197951	-1801	81398		
GC0417	375136	1151409	4969R	0	108419110	65529149418197947	-1750	81399		
GC0418	375132	1151384	4978R	0	116419103	65566149409197941	-1683	81450		
GC0419	375128	1151358	5011R	0	120419097	65604149207197935	-1567	81461		
GC0420	375123	1151330	5052R	0	131419088	65645148926197928	-1450	81442		
GC0422	375131	1151277	5179R	0	162419105	65723148587197940	-607	81889		
GC0423	375142	1151254	5252R	0	223419126	65756148590197955	50	82370		
GC0424	375152	1151232	5350R	0	212419145	65788148069197970	448	82413		
GC0425	375163	1151209	5476R	0	300419166	65821147209197987	761	82384		

END OF LIST

COAL VALLEY GRAVITY DATA

PROFILE GC-5

STATION IDENT.	LAT. DEG MIN	LONG. DEG MIN	ELEV. +CODE	TER-COR. IN/OUT	NORTH UTM	EAST UTM	GRSV GRAV	THEO GRAV	FAA	CBA +1000
GC0502	374746	1152530	5718F	0	193418359	63897144526197377			966	81656
GC0503	374743	1152503	5718F	0	173418355	63937144489197373			931	81602
GC0504	374736	1152478	5685R	0	163418342	63974144749197363			888	81662
GC0505	374730	1152451	5654R	0	154418332	64014144987197354			843	81714
GC0506	374723	1152425	5618R	0	147418320	64052145064197344			594	81580
GC0507	374717	1152399	5578R	0	144418309	64091145007197335			165	81286
GC0508	374711	1152372	5536R	0	141418299	64130144846197327			-362	80878
GC0509	374705	1152346	5501R	0	134418288	64169144755197318			-789	80582
GC0510	374697	1152319	5482R	0	131418274	64209144662197306			-1051	80382
GC0511	374672	1152210	5344R	0	120418231	64369145433197270			-1545	80349
GC0512	374643	1152096	5270R	0	113418180	64538146320197227			-1225	80883
GC0513	374613	1151991	5227R	0	112418127	64693147291197184			-690	81585
GC0514	374606	1151964	5210R	0	109418115	64733147233197173			-909	81431
GC0515	374599	1151938	5206R	0	108418103	64771147197197163			-975	81379
GC0516	374593	1151911	5206R	0	108418092	64811147162197155			-995	81356
GC0517	374587	1151885	5204R	0	108418082	64849147031197145			-1143	81217
GC0518	374580	1151859	5206R	0	109418070	64888146958197135			-1181	81171
GC0519	374574	1151833	5208R	0	112418059	64926146959197127			-1155	81194
GC0520	374567	1151806	5215R	0	118418047	64966147022197116			-1017	81315
GC0521	374560	1151780	5220R	0	121418035	65004147132197106			-845	81471

END OF LIST

COAL VALLEY GRAVITY DATA

PROFILE WR-5

STATION IDENT.	LAT. DEG MIN	LONG. DEG MIN	ELEV. +CMDE	TER-COR. IN/OUT	NORTH UTM	EAST UTM	GRSV GRAV	THEO GRAV	FAA	CHA +1000
WR0501	38 146	115 887	5984Y	0	209420993	86257145223	199423	2119	81919	
WR0502	38 131	115 915	5895B	0	190420964	86217145697	199401	1776	81860	
WR0503	38 131	115 943	5809H	0	181420963	86176146080	199401	1359	81726	
WR0504	38 134	115 972	5744H	0	169420968	86133146346	199405	998	81577	
WR0505	38 138	1151003	5685B	0	158420975	86088146651	199411	559	81394	
WR0507	38 154	1151055	5554H	0	135421003	86011147152	199434	-13	81178	
WR0508	38 172	1151065	5521B	0	145421036	85996147285	199461	-212	81101	
WR0509	38 179	1151086	5480B	0	132421048	85965147522	199471	-371	81069	
WR0510	38 176	1151114	5442B	0	125421042	85924147754	199466	-500	81065	
WR0511	38 178	1151142	5399B	0	123421045	85883147998	199470	-658	81049	
WR0512	38 180	1151170	5358B	0	118421048	85842148203	199473	-848	80997	
WR0513	38 185	1151198	5317H	0	117421056	85801148381	199480	-1056	80925	
WR0514	38 188	1151225	5280B	0	115421061	85761148423	199484	-1373	80735	
WR0515	38 188	1151254	5241B	0	114421060	85719148401	199484	-1756	80461	
WR0516	38 185	1151282	5208B	0	109421054	85678148416	199480	-2066	80285	
WR0517	38 178	1151399	5088Y	0	98421037	85507148840	199470	-2765	79986	
WR0518	38 187	1151506	5014B	0	94421051	85350148722	199483	-3577	79417	
WR0519	38 197	1151614	4998B	0	83421067	85192148112	199498	-4347	78689	
WR0520	38 207	1151724	5009B	0	78421082	85031147740	199512	-4688	78326	
WR0521	38 216	1151832	5015B	0	77421096	84872147648	199525	-4677	78294	
WR0522	38 219	1151859	5019B	0	77421101	84833147720	199530	-4579	78381	
WR0523	38 222	1151887	5022B	0	78421106	84792147835	199534	-4433	78515	
WR0524	38 224	1151913	5027B	0	78421109	84754148003	199537	-4228	78705	
WR0525	38 226	1151940	5031H	0	80421112	84714148257	199540	-3941	73941	
WR0526	38 229	1151968	5036B	0	81421116	84673148559	199545	-3593	79312	
WR0527	38 231	1151995	5041B	0	83421119	84633148853	199547	-3251	79638	
WR0528	38 233	1152022	5046B	0	86421122	84594149161	199550	-2897	79977	
WR0529	38 236	1152050	5052B	0	92421127	84553149493	199555	-2519	80343	
WR0530	38 239	1152076	5057B	0	97421132	84515149908	199559	-2064	80786	
WR0531	38 241	1152104	5065B	0	114421135	84474150390	199562	-1505	81334	

END OF LIST

